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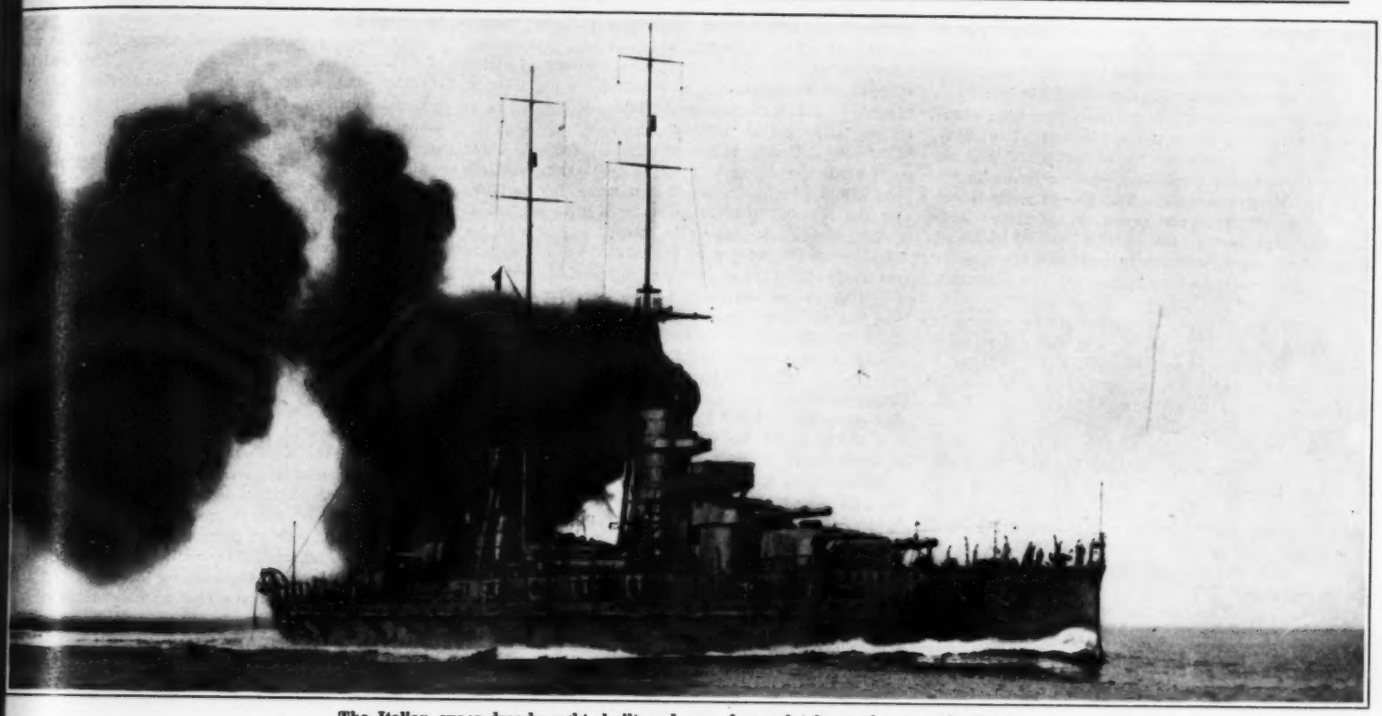
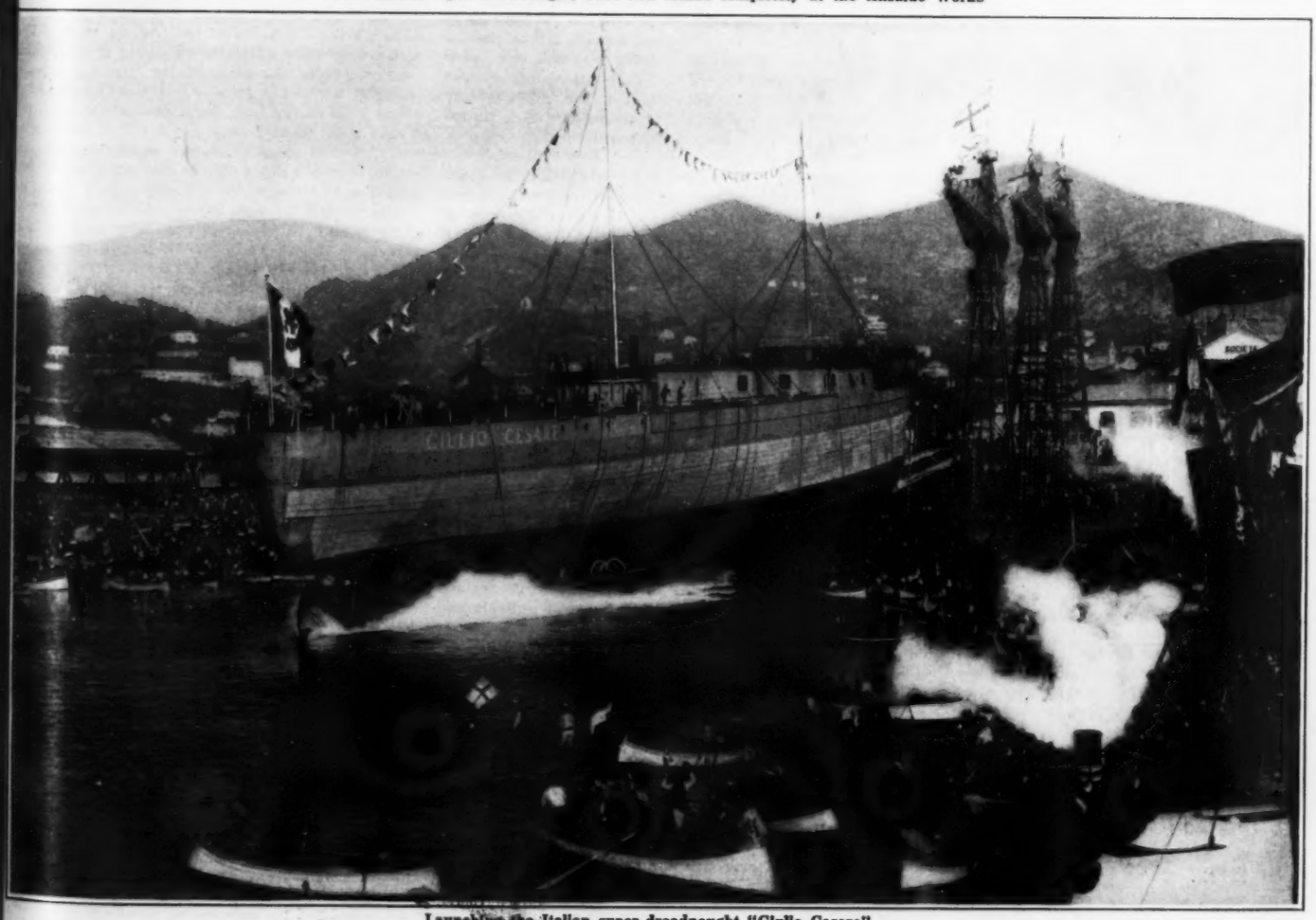


The Italian super-dreadnought, built and armed completely at the Ansaldo Works



Launching the Italian super-dreadnought "Giulio Cesare"

MODERN TECHNICAL WORK IN ITALY—[See page 104]

The Energy of the Universe*

Some of the Ways in Which We Transform and Use It

ALL cosmical speculation more or less tends to place the earth, and with it mankind, in a seemingly very subordinate position in the Universe, so much so, that but a few centuries ago advances claimed in the realm of physical knowledge were met with vigorous opposition from schools of thought claiming the right to define the territories of so-called spiritual understanding. The earliest known records of cosmical speculation indicate that the Chaldeans 3,000 years B. C. held quite logical views about the mechanism of the Universe, and this without (so far as is known) the aid of refinements having the high order of accuracy known to-day. Although these ideas were passed on from age to age, but little progress was made by the students of ancient days, owing to the predominant evidence of the physical senses, which invariably act contrary to the knowledge we have that "things are not what they seem."

The possibility of apparent motion, for instance, was not realized at all. Because no one had felt or seen the earth move, its proved immobility followed as a matter of course; also, was it not clearly demonstrable that the sun rose in the east and set in the west? Thus it was the Ptolemaic theory came into vogue. This conception of the Universe held its own for a considerable period of time and assumed that the earth was fixed immovably in the central position, and that the moon and planetary bodies revolved around it. Above these was the firmament of fixed stars, the crystalline orbs, the *primum mobile* and the heaven of heavens. Each star was supposed to be fixed in a solid transparent sphere like crystal, and to account for their motion geometrical assumptions were called in. If any new discovery was made, well, it was quite a simple matter to account for it by adding new crystals. This conception of things is referred to by Milton in the eighth book of his "Paradise Lost." In the sixteenth century the Tychonean conception of the Universe was promulgated, in which it was supposed the sun, with all the planetary bodies, was carried about the earth in the space of a year, these again by regular motions moving round the sun in their individual periods. This age was, however, an inquiring one, and for lack of proof this theory did not gain much credence. Finally, during the same century, the first real light upon darkness enters with the Copernican theory. This mental vision of things reverted back to ancient ideas in its main elements, and, verified later by Newton and other observers, holds good fundamentally to-day. Think for a moment of the courage such a step demanded; when, conscious of the opposition such a course would create, a doctrine was issued which at a single blow deposed the earth from its thought-to-be position of immobility as the center of the Universe and throne of spiritual dominance; which broke through the supposed solid firmament and rejected the ideas of an upwards or a downwards?

To the thoughtful mind nothing can be more self-evident than the vastness of the Universe, and, as the mind of man tends toward investigation, from a mere contemplation of effects, inquiry into the causes which produced them and aids to that end naturally followed. What, for instance, was motion, space, time, or matter? Who is there can yet give an answer to these inquiries in terms of the absolute? Let us, however, never be backward in recognizing what a tremendous debt we owe the early pioneers, many of whom have passed into the Great Beyond without posterity knowing even their names. It is recorded that on a celebrated philosopher being asked to explain the nature of motion, he got up and walked, observing that although unable to define it he would show what the thing itself was. It is merely asserting a truth if I say we know nothing at all of absolute motion, or the veiled energies of the celestial bodies, for our present consciousness recognizes relative motion only. We speak, for instance, of a train traveling sixty miles an hour. In such a case at least three other motions are simultaneously involved. First, we have the movement of the earth as a result of its own rotation; considered as relative to a point on the Equatorial line this approaches 1,000 miles an hour. Secondly, its revolutionary movement round the sun at over 64,000 miles an hour; and thirdly, over 43,000 miles an hour as a result of the combined motion of the solar system with which the earth is at present most actively associated. Some rude idea of the immense energies operating under this aspect may be apparent if it is recalled to mind that the earth (which is over 90 million miles from the sun) moves round that orb in a mighty sweep of over 500 million miles during the year. Our utmost powers of space expression are surpassed, however, when an attempt is made to follow the immense depths which those mysterious bodies called "comets" traverse.

Entering into the realm of physical force in their more commonly recognized forms, remarkable distinctions are to be found. Observation shows, for example, that the force of gravitation operates upon masses of matter, without, so far as is known, any regard for the physical components of the matter itself. We are also used to thinking of pressures in terms of thousands of pounds to the square inch in engineering construction, but we know little or nothing of the vast pressures wherein millions of tons to the square inch are exerted across space. Again, no explanation is yet forthcoming showing why iron, and iron only, in particular conditions is magnetic. Going still further, one may grasp in the hand an electric conductor, acting as a directing agent for what is represented as energy in terms of thousands of horse-power, without being at all conscious of its transmission. To the uninitiated the nature and character of electricity is a profound mystery, and the mental attitude exhibited by a celebrated Chinaman, who, upon seeing for the first time an electric tramcar in motion, then attempted to run from the vicinity, exclaiming, with astonishment, "No pushee! No pullee! Go like hellee!" is easily understood.

How does the energy of the distant generator or dynamo reach the car in, for example, a modern electric tramcar, having motors, apparently fed with energy from an underground conductor? No propelling strain can be proved to exist on either the connector or the underground conductor, yet it is certain the energy is transmitted via some medium, converges upon the car motors, and propels it as desired. Think, now, of a modern steamer traversing the ocean thousands of miles away, and yet by means of the infinitesimal energy directed from a given and prearranged wireless station being able to still keep in touch with the distant shores. The commonly known conductor is in this case actually non-existent. Truly may it be said, "Eyes have we, yet see not; ears, yet hear not." Here I will ask you to try and realize that the day is not far distant when smoke will be eliminated, fogs dissipated, cars propelled, cities lighted, dwelling houses heated, and local space ideas of separation annihilated without visible conducting mediums being necessary at all, for nothing is more certain but that the whole of the surrounding space which the earth traverses in the Cosmos is permeated with the governing principle for manifesting the truth of the statement. Periodically the world is startled by the news that some great discovery has been made and a new law of Nature laid bare; yet it is self-evident all such laws must have existed ever since time was, and have, therefore, been available in all ages. Centuries ago it was known to chemists that the formation of successive elements was attended by either the generation or freeing of large quantities of energy. To-day the modern chemist endeavors to build up the stellar systems of space out of about ninety elements, some of which, in proper union, are capable of demonstrating enormous energies. The invisible gases hydrogen and oxygen form a good example. Mix in a suitable container two volumes of the former to one of the latter and bring near the mixture a flame; there instantly follows a bright flash of light, accompanied with an explosion. This is the result of chemical combination; but what has occasioned such an exhibition of energy? The formation of a single drop of water. Water is formed by the chemical union of 1,800 times its volume of the two gases named, and the amount of energy required to form one pound of it is sufficient to raise a weight of over 2,200 tons one foot high. Yet a single oak tree 100 years old will, in the course of its existence, have given off nearly 20,000 tons of water. Imagine what would happen if the unknown forces controlling the molecular constitution of water over the entire globe broke down, and the energy contained therein was released. Life, as at present known in the physical sense, would be as formless as is the common seaweed of to-day. Manifestations of energy exist everywhere throughout the universe in a multitude of conditions, but of the thing itself we know nothing. The philosopher may speculate and the theorist dream, but neither has proved.

Now consider the sources of energy from the point of view of their association with the economic activities of life. These may be briefly summarized as those associated with: (1) Agriculture; (2) mining; (3) manufactures; (4) timber cultivation; (5) transportation; (6) collection and distribution; (7) cattle raising and fishing; (8) public services and utilities. The development of civilization has been marked by certain ages, each more or less connected with materials used in advancing the welfare of the ruling peoples concerned; thus we have the Stone Age, the Bronze Age, and the Iron Age. The present age may aptly be termed the Coal Age; the purely Electrical Age is rapidly approaching, and, with it, greater wonders than any known to-day; while further ahead still lies the dimly perceived age of metaphysics, producing thought creations of a new order and conferring great benefits upon mankind. Human energy by itself is the sum total derived from the combination of thought intelligence, plus muscular activity, demanded from the manual labor attached thereto, and the headings given will, it is thought, be fairly representative ones, wherein, under normal conditions, the great nations of the world group their activities. Sources of energy may at present be divided as follows: (1) Solar energy; (2) tidal energy; (3) internal heat energy; (4) radioactivity. Under prevailing conditions of thought, we are so entirely dependent upon the unchangeable manifestations of solar energy, and these elements are so well known, that it is unnecessary to dilate upon them, other than to remind you its withdrawal would spell a calamity which no present form of life could escape the physical consequences of. Tidal energy is a matter that does not yet appear to have been seriously worked upon, with a view to utilizing it in a practical form on a large scale. Although the difficulties of constructing wave motors with commercially adaptable regulating devices appear complex, possibilities for obtaining large quantities of energy at low cost in suitable localities undoubtedly do exist. Heat energy from the interior of the earth is a subject about which I have seen but little information, and, generally speaking, energy obtainable from volcanoes, geysers and hot springs does not enter into consideration as a competitor with other known quantities. (Quite recently, however, steam turbine engines capable of developing 45,000 horse-power have been installed in central Italy. These engines derive their power direct from hot steam, collected from a volcanic source by large pipes; are, I believe, the first so operated by the energy of a natural boiler, and generate electricity.) The ruling given likewise applies to radioactivity, but in this case a vast field for the research worker exists. As an example, it is estimated that the complete decomposition of one ton of radium is a matter taking thousands of years to accomplish, yet the heat energy developed during one hour alone is sufficient to raise the temperature of one ton of water to the boiling point. In adapting the different forms of energy to man's needs, the muscular effort from manual and animal labor obviously led the way, and as the desire to obtain a more complete command of the conditions of existence, coupled with a knowledge of the resources available, grew, pre-thought limitations governing the control of these resources step by step disappear, until the present position of affairs is reached. Originally all work was done by hand, and this still prevails in some parts of the world, more particularly where difficulty exists in utilizing labor-saving devices and labor itself is cheap. Under the different forms whereby energy can, as it were, be controlled so as to do work for man, the most important embrace winds, water, and fuels. Without these the development of modern industry and comfort would not have been possible, for the thought growths of civilization have been essentially dependent upon the manifestation of power and ability to utilize it along the most advantageous lines. Energy derived from wind dates back to antiquity, and its greatest utility has undoubtedly been in connection with water transportation requirements. Numerous conditions also still exist where mills for the grinding of cereals and the pumping of water are to be found, but, generally speaking, the unreliability of wind as

*From an address given by Mr. A. L. Stanton, Associate Member I.E.E., at the Swansea Public Library on January 9th, 1917. Reported in the *English Mechanic*.

regards its continuity and velocity are factors tending to limit its application on large scales. Like unto that of internal heat, it is as an agent of *destruction* that the energy of wind is best known, and when thus associated with that of tidal energy, the annual losses of life, shipping disasters, coast erosions and storm-swept continents tell in the aggregate a tale of stupendous dimensions. Turning to the use of water-power, it is found to also date from antiquity, for the problems of irrigation were among the first to demand attention from the earliest pioneers of industry. During the last decade, the utilization of water-power has become an extremely important thing, and is best known in this country in the character of hydraulic power. Thus it is found in use in the majority of large docks and large cities as a lifting agent, and wherever fortification engineering works are in evidence it has an exceedingly important duty in the military sense. Its most important application, however, lies in operating the prime movers for the generation of electric power. The vast annual consumption of modern fuels in the shape of coal and oil, supplemented by the fact that many centers of human activity exist where the fuels named are scarce and only obtainable at prohibitive prices, largely accounts for this, and, as necessity was ever the mother of invention, so the last two decades have witnessed immense strides in the production of machinery whereby water-power running to waste could be utilized for the benefit of the immediate localities concerned. From this point of view it is estimated that something like 700 million horse-power is available from the known sources of water-power in the world, but, of course, this vast amount cannot as yet be economically developed. With the fuel forms of energy becoming more and more limited, as time proceeds, the possibilities of the future for water-power development become of the highest importance, and, although such powers are not available in this country on anything like the scales commanding attention on the great continents, many parts of the British Empire are more fortunately situated for association with great electric power schemes. It would be presumption on my part to tell an audience in this part of the world anything regarding the value and extent of coal and oil as fuel forms of energy, but, referring to the latter, it may be of interest to note that over 170,000 oil wells are in operation in the United States of America alone, some of which are over a mile deep.

In dealing with the numerous transformation forms of energy which are known to-day, few will contradict the assertion that electricity is the most convenient and flexible form whereby energy can be transmitted, distributed and utilized. As at present understood, it is not of itself a source of energy, but is manifested directly or indirectly from transformations of either a chemical or mechanical nature. No other at present known form of energy conversion can approach it for utility possibilities under the headings of high efficiency, reliability, storage capacities, conservation of power, or the ease whereby it can be applied to practically any demand human desires expect from it in the nature of making it a servant. Its function in the scheme of natural causation as regards the fixation of nitrogen has, moreover, yet to be realized, for it seems but little known that every atmospheric electric discharge, silent or otherwise, is full of the goodness of Nature to organic life. Peculiar as it may also appear, the manufacture of destructive munitions on the immense scale at present demonstrated by all the manufacturing nations of the world through the struggle now in progress is an element which is steadily eating into the reserves of natural energy available under this aspect.

The Effect of Successive Removal Upon the Rate of Regeneration*

By Charles Zeleny, Zoological Laboratory, University of Illinois

ONE of the most interesting facts in connection with regeneration is the ability to replace a part after repeated removal. Former studies by the writer show that as a rule the rate of regeneration following a removal is no greater than that following second and later removals if the effect of age is eliminated. Where a difference exists it is in favor of the later regeneration.

The matter is of very great interest in connection with general problems of development and particularly in connection with the question as to the existence or non-existence of a necessary limit to the amount of living substance that a single individual may produce during its life cycle. Does the production of a group of tissues use up a part of a certain store of developmental energy possessed by the individual or is this store inexhaustible or perchance even increased by the exercise of the function? These questions warrant more extended study especially in view of the additional analysis that has been made of other factors controlling the rate of regeneration. The new data support the conclusion previously reached and make possible a further analysis of the character of the difference between successive regenerations.

In making a comparison of successive regenerations a method must be devised for eliminating the effect of age. If the rate of a second regeneration is compared with that of a first regeneration in the same individual any difference that is made out may be due not to the pure effect of successive injury but to the effect of difference in age.

The method pursued in the present experiments consists in the initial removal of a portion of the tail in one half of a set of Amphibian larvæ of equal age. When regeneration has proceeded for several days there is a second removal of the part accompanied by a first removal in the half of the set that had not previously been operated upon. The second regeneration that ensues in one half of the set may be compared directly with the first regeneration in the other half. There is no difference in age.

In experiment I. approximately one half of the tail was removed in tadpoles of the green frog, Rana clamitans. At six days the average first regeneration length is 2.01 millimeters and the average second regeneration length 2.18 millimeters. The first exceeds the second in five sets and the second exceeds the first in six. The corresponding specific lengths or lengths regenerated per unit of removed length are 0.194 and 0.205. The first regeneration exceeds the second in two sets, the second exceeds the first in five and one is tied. The second regeneration has the advantage in all the comparisons.

At eight days the average first regeneration length is 3.06 millimeters and the second 3.42 millimeters. The first exceeds the second in three sets and the second exceeds the first in seven. The corresponding average specific lengths are 0.298 and 0.323. The first regeneration exceeds the second in four sets and the second exceeds the first in six. The second regeneration has the advantage in all the comparisons.

This advantage of the second regeneration over the first in experiment I. holds true of second regenerations from both old and new issue levels.

In experiment II., also with Rana clamitans, operations were made at the 1/10, 1/3, 1/2 and 2/3 levels in a sufficient number of individuals to yield valid data. Regeneration measurements were made at each of these levels 4, 6, 8, 10, 12½, 18 and 56 days after the operations. The second regeneration at these levels is ahead of the first until about the twelfth day, after which the first regeneration catches up. The maximum rate for both regenerations is reached before this time, and earlier for the second than for the first regeneration.

In experiment III. two thirds of the tail was removed in larvae of the salamander, Amblystoma punctatum. A comparison of the first, second and third regenerations was made at 2, 4, 6, 8, 10 and 14 days. At two days the first, second and third regenerations average respectively 0.22, 0.25 and 0.26 millimeter. The corresponding values at four days are 0.66, 0.75 and 1.00; at six days 1.36, 1.40 and 1.36; at eight days 2.18, 2.68 and 2.68; at ten days 3.55, 3.82 and 4.20; at fourteen days 5.34, 6.12 and 6.08. The advantage is in favor of the second and third regenerations as opposed to the first and of the third as opposed to the second. Individual comparisons at each of the different times show similar results.

The evidence as a whole shows clearly that when the age factor is eliminated there is no decrease in rate of regeneration with successive removal. On the contrary the second regeneration is more rapid than the first up to the period of maximum rate. The second regeneration, however, passes its maximum sooner than does the first and after the tenth day the latter therefore catches up in total amount regenerated. There is no striking difference between the second and the third regenerations, but in each comparison the third has a slight advantage.

When successive regenerations within single individuals are compared there is a progressive decrease in rate and it is obvious that this is due to age.

The possibility has suggested itself that the second regeneration starts out at a more rapid rate than the first because the cells at the cut surface were undergoing regenerative changes at the time of the new operation and can therefore start the process much faster than can the old cells at the first surface of regeneration. Following a first removal there is a considerable degree of reorganization of the cells at the cut surface, accompanied by active migration. During this period, which in Rana clamitans lasts two or three days, there is little or no mitotic cell division. Then follows a division period which reaches its maximum at seven to ten days. Its decline is associated with the oncoming of tissue differentiation.

A special study has been made of the relative rates of second regeneration from old cells following a cut inside of the first removal level and from new cells following a cut outside of the first level. This comparison shows only a very slight difference in favor of the new cells and this is largely confined to the early stages, the period of cell migration.

The period of increase in rate is the period of active cell multiplication and the decline in rate is associated with cell differentiation. The second regeneration therefore reaches the period of differentiation slightly in advance of the first regeneration.

Apart from the slowing due to age there is no indication of a limitation of the amount of new material that may be produced by regeneration. The actual limitation comes not from the using up of regenerative or developmental energy or of "determiners" by repeated regeneration, but from changes in the non-regenerating part associated with age. In another place there is a discussion of the possibility that there may be an effect upon the rate of developmental processes in the organism as a whole due to continued regeneration of a part. This is studied particularly in connection with the effect of regeneration upon rate of metamorphosis in Amphibia.

Regeneration studies in general and those on successive regeneration in particular make it improbable that there is a definite number of cell regenerations between the fertilized egg and the end product, the differentiated cell. The possibility that certain cells may remain in an early cell generation can not be wholly excluded as an explanation of at least part of first regeneration phenomena. Under suitable stimulation such cells may be postulated to take up development where it has left off. The definite descriptions of de-differentiations of cells as well as other facts of regeneration argue against this conclusion. The view that there can be no such definite number of cell generations is strengthened by the facts of successive regeneration. It does not seem probable that embryonic cells of an early cell generation can be held in reserve through repeated regenerations.

The explanation of regeneration by the theory of duplicate sets of determiners meets difficulties in undiminished successive regenerations. The greater the number of repeated regenerations the greater the difficulties of explanation on this basis. Of course the difficulty does not hold for the hypothesis that every cell or nearly every cell contains a full set of determiners.

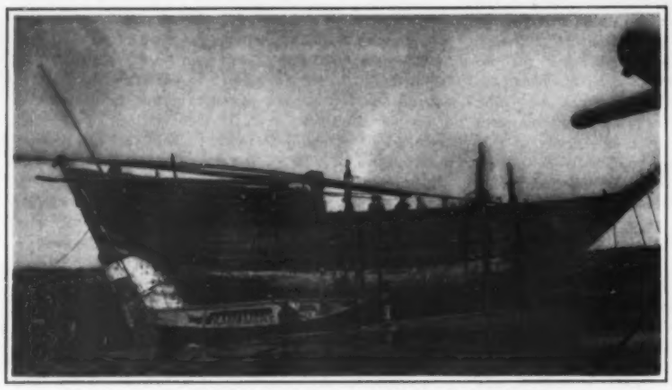
The earlier appearance of the maximum rate in the second than in the first regeneration may be due to the more rapid progress of the cells in the early cell migration period alone, or it may be due to the acceleration of the whole developmental cycle.

The full data will be published in the University of Illinois Biological Monographs.

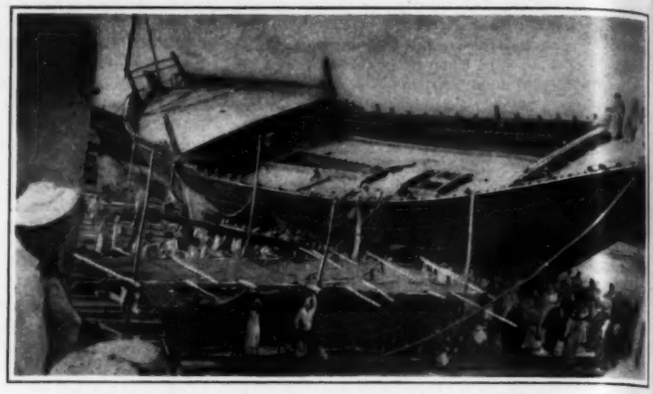
*A paper read before the National Academy of Sciences, and published in the *Proceedings* of the Academy.

Recent History of the Cotton Boll Weevil

A PAPER by W. Dwight Pierce gives interesting facts concerning the recent movements of the cotton boll weevil in the United States. From a study of specimens collected in all infested regions of North America it appears that there are three lines of dispersion. The weevil probably originated in Guatemala or somewhere else in Central America. The most typical strain migrated northward through the mountains of Mexico into Arizona, where it now occurs on the wild cotton-like plant *Thurberia thespesioides*. The most important line of migration was along the Gulf coast through cultivated cotton regions into the United States. Lastly, another line of dispersion was through Yucatan and across the Gulf to Cuba. A noteworthy fact is that specimens collected at the termini of these different routes are very distinct varieties, that found on our cultivated cotton being the smallest and the most variable. During the past year the weevil has spread to the northern limits of cotton growth in Oklahoma and Arkansas, into central Tennessee, and eastward to the Atlantic Ocean south of Savannah. Practically all the cotton region of Florida is now infested, and the only sea island cotton section not infested is that of South Carolina.



The Arabs are still building the kind and size of boats that Columbus used. The Portuguese were powerful in the Persian Gulf during the sixteenth and seventeenth centuries



Largest type of vessel recently built on the Persian Gulf. It is 500 tons burden, and carries dates and meats to India and Africa. These vessels seldom go out of sight of land

The Pearl Fishing in the Persian Gulf

Where the Finest Gems in the World Are Found

By Edwin E. Calverley

THE finest pearls in the world come from the Persian Gulf. There are pearl fisheries in America along the Mississippi River and in the Gulf of California, in Australia and Ceylon and other places, but these fisheries produce valuable pearls only occasionally. The Persian Gulf, however, is perennial in its supply, and the pearls produced there are those most prized in America, as they have the luster and symmetry that the American lady requires when she selects pearls. Only a small proportion of the Persian Gulf pearls, however, reach America.

The pearls are gathered by divers and sold to brokers at sea, and sold again by them to dealers in Bahrein or Bombay, who send the pearls to Paris. Here the pearls are sorted for the different markets. White pearls can easily be worn by fair English ladies, but they would never do for a South American beauty. They would only make her complexion seem darker than it is. Irregular pearls may find a place in the abundance of gold ornaments that an Italian lady will wear, while a pearl with flaws will not destroy the effectiveness of the ropes of pearls on a Russian princess. But symmetry, quality and color are demanded of every pearl to match and heighten the bearing and beauty of the American lady. So Paris selects the finest and largest of the thousands of pearls that come there and sends them over to America.

No Westerners are engaged in the Persian Gulf pearl fisheries. When the British government began making treaties with the tribal chiefs along the Arabian coast, they promised to protect the gulf waters from piracy, and they have reserved to the natives their immemorial rights to the pearls there. To this day, therefore, only Arabs, Persians and negroes do the diving. About 100,000 are engaged in the business. Most of them live in the towns and villages of the Arabian and Persian littorals. These coast dwellers are the best workmen, for they are acquainted with the sea. They are preferred also because they are known to their employers and are under the authority of the local sheiks. But in some years the demand for divers is so great that men come from Busrah, Bagdad and Aden. Even from Central Arabia, where there are no lakes and rivers, men and boys come. In spite of their ignorance of the sea, and the uncertainty of the hold their masters will have upon them, they are engaged.

There is seldom any difficulty in getting workers. No regular wages are paid, but the proceeds of the season's catch are divided among those engaged. The work is hard, but it lasts only about six months, and the diver expects to live on his share the rest of the year. The uncertainty of the reward makes the business a gamble that is very stimulating to the already vigorous Oriental imagination. Often the season's work does make every member of the crew an independent gentleman for several years. Just as American boys have their ambition and energy aroused by tales of newsboys becoming millionaires, so the Arabs tell about boys who searched the streets for date-stones, and then became divers, and are now possessed of numerous harems and of lacs of rupees, which is the Oriental way of saying millionaire. The richest man in Kuweit is reputed to be worth about twenty lacs, about $650,000, and when he was a boy he gathered date-stones to be ground up and fed to camels and donkeys.

THEIR SPECIAL BOATS.

The pearling boats are built with the special requirements of the industry in mind. The decks are never high above the water-line, and are often within arm's reach of the diver in the sea. They are all sailboats, and in calm weather are moved from place to place by rowing. The pearling fleet offers an untouched market for motor-boat manufacturers. One Arab boat-builder and pearl merchant questioned me in detail about how and where he could get a motor-boat, and also an attachable motor. The lumber for the native boats is all imported from India. It is merely trees sawed lengthwise into boards. The ribs are crooked branches. The ship-builder uses six tools for his work: an adz, a hammer, a saw, a chisel, a plane and an auger. The nails are made of soft wrought iron and have large heads. Holes are bored through the hard boards and ribs, then the nails are hammered through and clinched on the inside. The lumber is not shaped in any way, so irregular spaces are left and these are patched very cleverly. The Arabs are not carpenters because theirs is not a wood country. When lumber was brought into the gulf a hundred or more years ago, carpenters from Persia were brought to the Arab towns. They were of a different sect of Mohammedans, and they have maintained their distinct characteristics through the four or five generations since.

Every pearling boat has a large water tank, which is shaped to fit snugly into the sides of the boat. Iron tanks were introduced a few years ago and, although they were less expensive than wood, the rust discolored the water. This is too precious for the Arabs to throw away, so the wooden tank is returning to favor in spite of the fact that it does not hinder the breeding of worms in the water. The Arabs have adopted the English name for the water container and call it a *tanky*. The plural, *tawanky*, is hardly recognizable.

The equipment for a diving season is not extensive. The boat itself is given a coat of fish oil instead of paint. This fish oil is something to be forgotten, and its odor must be what keeps barnacles away. In the early spring, when the nearly naked divers daub the oil on their boats, and get it all over themselves, the sea-front is a place to be shunned. Then the sails are repaired and the rigging is put in order. The supplies are put on board; bags of rice, tins emptied of Standard oil and filled with *dihin*, which is the Orient's oleomargarine, baskets of the cheapest dates, dried fish, tamarinds and onions to ward off the scurvy, are the provisions stocked. Then each man provides his own tobacco and matches, ropes, cord-nets, finger-stalls and nose-stoppers, which are like clothes-pins, and are used to help the diver to hold his breath under water. Date-stick fish traps are also taken along to catch fish at night when the boat is anchored and all is quiet. The last thing that is done is to fill the water tanks.

PERSONNEL OF CREWS.

The crews are always of mixed races. Just as the sheiks of the towns will have men of different sects and from different regions in the customs house, each to watch the other, so the *naukhadhas*, or captains, will have some town Arabs, some Bedouins, some Nejdies, some Bagdadies, some Persians and some negroes on their boats. If there is a majority of any one kind on the boat it spells trouble for the rest, and sometimes results in disaster, as we shall see. The Shiah Muslims are not supposed to eat out of the same dish as other less enlightened mortals, but their religious scruples are of little weight on the pearl boats. The work of the crew is specialized. Of first importance are the divers, who do little of the work of fitting out the boat, for their hard work is in the water, not in the boat. Complementary to the divers are the rope-pullers, who are usually strong young fellows, not afraid of work, and their business is to save the strength of the divers all they can. Besides these there are the cook and the handy-man, who repairs the ropes and nets and catches fish when he can. He may also be called upon to do some extra praying and give the benefit of it to a diver who is engaged in too valuable worldly work to stop to gain heavenly merit for himself.

SELECTING CREWS.

The crews are gathered together early in the spring. As soon as the sun begins to warm the waters of the gulf, crowds of young men flock to Kuweit, Bahrein and Dubai, on the Arabian coast, and to Bunder Abbas and Linga, on the Persian side, where in the coffee shops they meet divers already engaged. These are eager to have good workers and cheerful companions with them, so they take their favorite acquaintances to their captain. The captain meets the new men in his house, and courteously inquires whether the recruit is free to enter his employ. Not so cordially he asks how much of an advance the diver or rope-puller will want. This advance is a credit the men nearly always need, as they must provide their personal equipment and tobacco and any other extras. If they are married they also want money to support their families during their absence, as they will have no means of sending money home, even if they had it, once they are at sea. To a desirable man the *naukhadha* will be willing to advance perhaps three hundred rupees, a hundred dollars, with the agreement that the diver will pay it back out of the share of the catch he will receive, with sixty rupees additional for the use of the money. The diver makes his mark to that contract, and thereafter he must work on that boat until the debt is paid, as no other captain will employ him until he is free. The only way a diver can be released from service under a *naukhadha* he dislikes is to get some other one to advance him enough to repay the former. This is sometimes done on the urging of captains or crews that want a particular diver, and then it creates no little ill-feeling among the employers.

THE DIVING SEASON.

No captain can begin his pearling season when he pleases, for this is determined by the sheiks in consultation with their counsellors. An *Amir al Ghaus*, or commander of the pearl fleet, is appointed as the personal representative of the sheik, and he it is who officially announces the opening of the season by the firing of a cannon. He also similarly closes the season. The rules prevent any captain from working his men when the water is dangerously cold.

The men all work happily together to pull their boats off the beach where they have rested all winter, and they are a cheerful crew as they start off for their fortunes. There are no good-bys to their women-folk at the boatside, for they have said their farewells in their homes, although their wives sometimes follow at a distance and sit crouched and bundled up against a wall and watch the departure of their lords through a small opening of their veils, but there is no waving of handkerchiefs as the sails are raised or the rowers get out their oars. Among the Bedouins of the desert the submergence of the women is not so marked. The most touching thing I have observed in the East was a kiss that I happened to see a Bedou give his young wife who had accompanied him from their goat-hair tent of a home for some distance toward his boat.

The most propitious time for starting off is on Friday, just after the noon worship in the mosque, and the fleet makes a regatta sight that afternoon as it sails out into the gulf. It will be away from April till October, with a month's recess in between, and this is due to the fact that Ramadhan, the month of fasting, now falls in the summer time. Each year Ramadhan falls eleven days earlier, because the Muslim year is lunar. In 1915 it began on July 14th, and the present generation of divers will have their season broken for the next six years.

As soon as the boat reaches a bank that the *naukhadha* thinks is a good one the diving begins. A fire is started, the diver strips until he has only a loincloth about him, and then he adds finger-stalls and ties the clothes-pin affair for his nose around his neck. He gets into the water and, although it is cold, he puts his foot into a noose on a rope weighted with a stone or lead and down he sinks. At the bottom he grasps around among the coral and pulls off as many oysters as he can find and places them in the small net of cord at his side. When he can hold his breath no longer he gives a jerk on the rope, which is tied about him, and the rope-puller helps him to swim quickly to the surface. He scrambles on deck and rushes to the fire to warm himself, while another diver takes a turn. He has stayed under only about twenty-five seconds. As the season advances, and the water gets warmer, he can lengthen his time to two minutes.

The oysters are not opened as they are brought up, but are placed in piles before each diving team to foster a spirit of rivalry for the common good. There the oysters putrefy under the sizzling sun and open of themselves, so a pearl boat is no perfumery shop. The workers have little or no respite during the day, not even for meals. For breakfast the diver eats only a date or two and he takes a little of the strong Arab coffee. Once again during the day he again takes as much, for the Arabs know the danger of working in the water after heavy meals. The rope-pullers are more fortunate, for they may eat all they want, but their share of the money is not as large as that of the divers. All, however, join together in a large meal at sunset, and they sleep soundly after their day's work. The next morning before the diving begins the *naukhadha* takes the oysters and searches carefully for every pearl, no matter what its size, shape or water. He squats on the deck tailor-fashion, and scrapes the pearls out and rubs them off his knife onto his big toe. Sometimes he will have a long row of pearls of every size and value lined up on his toe. They may eventually rest on the breast of an empress. The *naukhadha* then wraps them carefully in a little red rag, and the men disperse to their work.

The shells are disposed of in various ways. The boats that are near their home ports, as those of Bahrein, keep their shells until they return home, and sell them to the German and British firms there. Needless to say that since the war the German business has been abolished. These firms used to employ women and boys to clean the shells, and then shipped them to Hamburg and London to be made into pearl buttons and other articles. The other fleets, as those of Kuweit, simply cast all their shells overboard, except some few which have protuberances that indicate that there may be pearls formed inside them. These shells are sometimes opened by the captains and sometimes sold by them to a broker on a gamble as to the presence and value of a pearl inside.

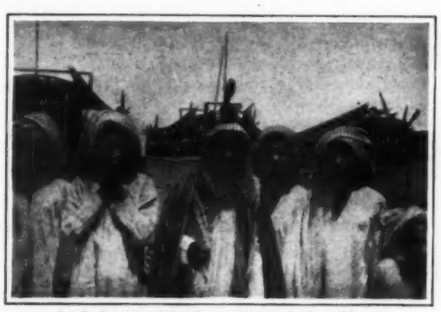
The divers work to an average depth of forty-eight feet, although some go down to sixty feet, and a few to even greater depths. An equipment which would allow them to reach 288 feet, which is an American diver's record, would be of tremendous advantage to the Arabs financially, as well as otherwise, since it seems to be really true that the largest and best pearls are at the greatest depths.

The lot of the pearlers is a hard one, for all run the risk of getting scurvy from the lack of fresh food. Ice, of course, is unknown in the fleet, and the impure water breeds worms. The boiling and filtering of water do not appeal to Oriental people as yet. The *saibs*, or rope-pullers, get palms as hard and cracked as an ancient Bedou's heel. They could prevent this by wearing gloves, but that would be a sign of effeminacy, and bring ridicule upon them. The exposure in the water gives many of the divers weak hearts and tuberculosis, and many of them become deaf because

Pearling boats of the Persian Gulf

the weight of the water breaks their ear-drums. Sharks do not create the scare that one recently did on the Atlantic coast. They abound in the gulf, and many divers have had a hand bitten off. One young Arab was brought to the American dispensary at Kuweit with his whole side laid open by a shark that had gotten a wide mouth-hold upon him. The boy survived. We asked him if he would give up diving now. "No," he said, "I will go back next year. I have to." The danger of drowning is great, for sometimes a strong current carries the diver far away from his boat, and before the rope-puller can bring him back he is drowned. The Arabs have no pulmotors, and they are not efficient in giving "first aid." If a man remains too long under the water, it was "written on his forehead," and that is all there is to it.

After the boat has been out a month, and an Arab coffee cup of pearls has been gathered, the workers get their first taste of luxury. A pearl buyer will visit their boat, bringing fresh vegetables, sweets, sherbets and tobacco, and all on board will get a share. The



Arab boys with the tablecloth headdress

captain is especially well cared for; and, after these preliminaries, the bargaining begins. It is carried on with many fine phrases and good wishes, with much criticising and weighing of the pearls. Pearls of special value are sometimes sold separately, but usually the pearls are sieved to show their size, and then weighed and sold in bulk. Finally a price is agreed upon and this is entered in a book. Frequently the *naukhadha* has hired the boat from one of these buyers, in which case it is understood that he will sell his pearls to that buyer, otherwise the buyer gets angry and demands the immediate payment of the rental. The result is, of course, that the buyer gets the pearls at his own price, for he has no opposition. Sometimes the broker and the captain unite to cheat the crew. The captain has a pile of pearls that he knows he can sell for $1,000, but he arranges with the *tawwas*, or broker, to accept $600, and put that amount down in the account book, with the understanding that some time the next winter the *tawwas* will give him an additional $200 which he will not have to divide among the crew. Then each has made $200, but the *naukhadha* has no redress should the *tawwas* fail to appear with the promised money.

At the close of the season the captain makes up his accounts. All the pearls he has sold may have brought him 20,000 rupees, or a single pearl may have brought that sum. It would sell for three times that amount in America. First, the captain takes out the amount paid for the rental of the boat; next, all the other expenses for food, water and fuel are deducted; and the balance is divided into shares. The *naukhadha* takes five shares; the *ghawwas*, or diver, gets one share; the saib receives two thirds or perhaps three fourths of a share, and the sheik takes a whole share. This is a tax for the privilege of working under his protection. It also gives the sheik access to the boat's book, so that he can see that the crew receive their rights. The captain deducts his advances to the members of the crew, and also his 20 per cent interest. Some years there is a considerable balance left for the divers; there will then be no trouble for the captains to get workers. But some years the individual shares are not large enough to repay the loans. Then all who can contract more loans to carry them on to the next season. If the sheik has a hold on the man, and the *naukhadha* values him, the man usually gets the sum he requires.

PIRACY IN THE GULF.

The pearl fisheries were formerly the favorite resorts of pirates, and one part of the Arabian littoral is still known as the Pirate Coast. The *bona fide* pearlers were all armed to resist attack, and they had constantly to be on their guard, for they could never tell but that some boat coming toward them that looked like a pearler changing its diving place might not suddenly turn out to contain a crew of pirates. The British gunboats have policed the gulf for a hundred years, and have practically stamped out the practice. Now it is almost unnecessary for a pearler to have a rifle on board, but if a captain does want to carry one, he must get a permit signed by a British consul in one of the gulf ports. But all know that if the gunboats were removed piracy would again flourish in a month's time. Every year the British send a small boat among the fleets, just to "show the flag." Even now the crews sometimes turn against their captains and practically become pirates. I knew an Arab named Razuki who fell a victim to one such escort to the Persian shore.

OPPORTUNITY FOR AMERICA TO BECOME THE PEARL CENTER OF THE WORLD.

Since the war the pearling business in the gulf has suffered almost to the point of ruin. Not a few bank and business failures resulted in Bombay and Paris right after war was declared. The French and British agents have not visited the gulf as in former years, and the Arabs have to dispose of their pearls in Bombay. There they are receiving a fifth of the former prices, or less, and they are selling only the pearls that are acceptable in that market. The best pearls they are hoarding until the European markets open. American experts could easily take the place of the French and British who have bought so many millions of dollars worth of pearls at Bahrein for America. No American firm has entered that field. The fact, perhaps, that they have not the old established markets that Paris has built up for the different kinds of pearls makes them hesitate, but the opportunity is there, and they would be welcomed.

"Re-Education" of Members Partly Amputated

In a paper presented to the Académie des Sciences, Professor Amar treats of the researches which are now being carried on by himself and others in what is termed the re-education of the wounded, that is, in regard to the use of the remains of such limbs as have been amputated. This question is one that is called on to have a great practical value in the countries which have suffered from the war. Various branches of science are concerned here, and one of the subjects which the author treats in the present paper bears on the estimation of the value of stumps of limbs remaining after amputation, and scientific researches in this field are going on at present in order to find out whether the stump is fit for "re-education," that is, can be made use of by an application of a suitable artificial appliance. The amount of power in this number needs to be estimated in the first place, in order to see how much work it can be called upon to do. He points out the means which are being used in laboratory practice for such measurements of power. The amplitude of the angular movements of the member upon its joint is evaluated in degrees, and other readings are made of the absolute power of the muscles which cause the movement. Comparing these results with the figures for healthy members, this gives at once a percentage loss resulting from the amputation. For measurements of this kind there is employed the "arthrodynamometer" and also an instrument termed "ergometric cycle," which terms are likely to become more familiar than they are at present. Again, the power of the truncated member varies with individuals, as might be expected, and in the present researches the above percentage comparison is noted for each subject, then the tests bear upon numerous subjects in order to figure the average results. For instance, M. Amar examined over 200 subjects whose limbs had been amputated.

On a Precision Method of Uniting Optical Glass

The Union of Glass in Optical Contact by Heat Treatment*

By R. G. Parker, B.Sc., A.C.G.I., and A. J. Dalladay

Owing to the numerous defects of the cements available for constructing glass cells for the examination of the optical properties of liquids, the following process, by which a much more perfect joint between two pieces of glass can be obtained, has been developed. Briefly, the surfaces of each of two pieces of glass are so worked and polished that they are either both plane or of the same curvature to a very high degree of accuracy. They can then be placed together in "optical contact," and if they are subjected to carefully controlled heating will unite and become one piece.

In order that this method may be of any value, it is essential that the temperature at which union takes place shall not only be far below the melting-point of the glass, but also below the annealing temperature, for even at this temperature very slight strain would cause sufficient deformation of worked glass surfaces to render them useless.

It is very difficult to place the windows of a cemented cell sufficiently accurately parallel for certain work depending on the phenomena of the interference of light; parallelism to ± 1 (one) minute is only attained with considerable trouble, especially if the adhesive material requires baking to cause it to harden completely. The wedge shape of the enclosed liquid may be too great for interference work, even if the angle between the windows is not greater than a few seconds.

In addition, cements frequently strain the materials which they hold together to such an extent that their optical properties are considerably altered. The interference rings are produced between the plate and a proof-plane of quartz; the plate was originally very flat, and showed less than one interference ring across its entire face. After cementing, the series of rings appeared, indicating a depression in the center of the plate of about 1/5000 inch. There appears to be considerable force acting radially inward; such distortion would render the glass plate useless for almost any accurate optical instrument, especially if polarized light were passed through it or interference phenomena were being observed.

Glass surfaces can be polished without difficulty so nearly flat, or so nearly of the same curvature, that when carefully cleaned and freed from dust, they show less than one interference fringe per inch when placed together and examined by light reflected from the interfaces. Such surfaces can be pressed into optical contact by the application of pressure of several pounds per square inch, and the pieces of glass act as one for optical purposes, for example, if the hypotenuse of a forty-five degree prism is in such contact with another piece of glass, no total reflection—indeed, no reflection at all—is obtained from the common surface. They can easily be separated by sudden warming or cooling, by force, if applied in a *peeling* manner, and by liquids; the latter gradually creep in and lift the surfaces apart. The joint is very resistant to forces tending to slide one surface over the other.

A cell constructed of two plates of glass in optical contact with a U-shaped separating piece would have the advantages of great accuracy of parallelism between the windows, very little strain in the windows if the components were of one kind of glass and put together at the same temperature, and an "all glass" construction, involving no cement to contaminate liquids placed therein, and to perish eventually under the action of solvents or corrosive substances. But it would be quite useless, owing to the ease with which such surfaces can be separated by the methods described above.

It is well known that if glass is heated it gradually becomes less viscous as the temperature rises, passing through all degrees of viscosity until at a high temperature it is quite mobile; there is thus no sharp melting-point, but only an approximate position, which varies from about 1,100 to 1,400 deg. Cent. At temperatures very much below the melting-point the glass is still liquid enough to deform gradually under stress, hence the slow permanent bending of a glass rod supported at each end, in a horizontal position and at ordinary temperatures. Glass behaves, in fact, as a brittle elastic solid under sudden strain, but as a viscous liquid to severe strain applied over long periods when at ordinary or moderately elevated temperatures; with rise of temperature the elastic nature of the glass becomes more and more masked by the decrease in viscosity, and at a temperature approximating to the melting-point it becomes no longer observable.

Annealing Temperature.—If a piece of glass having two plane, parallel, and polished sides is placed in an electric furnace so that it can be heated, and examined by transmitted polarized light at the same time, the strain caused by unequal heating can be observed both as regards position and intensity by its effect on the light. This strain, which would be very evident at lower temperatures in a piece of glass in the form of a one-half-inch cube or larger, suddenly disappears over quite a short range of temperature situated very much below the melting-point. The glass has obviously reached a temperature at which it is sufficiently mobile to accommodate itself rapidly to the stresses caused by unequal heating; it is therefore deformed, and the stress disappears; this is clearly the annealing-point, in that a piece of badly annealed glass would lose all internal stress at this temperature, and if sufficiently slowly cooled would be perfectly annealed.

Relation of the Temperature Employed to the Annealing Temperature.—The viscosity of a glass at its annealing temperature is still very great, but it has softened sufficiently for a pointed tool, pressed against it with considerable force, to make its way slowly in. Therefore, an optically worked surface of a piece of glass would not retain its form accurately after heating to the annealing temperature, if some clamping apparatus had touched the surface.

Glass becomes twice as "soft" for *every* rise of temperature of 8 deg. Cent. Therefore, at 60 deg. or 70 deg. Cent. below the annealing temperature a glass has become sufficiently hard to withstand very great local pressure for short periods without sensible deformation. The method of determining the annealing temperature will be described at a later date; it should be known accurately for each kind of glass which is to be joined, as by this means only can we obtain a sufficient welding effect together with the minimum risk of injury to the surfaces.

Working at this temperature, 60 deg. Cent. below the annealing-point, two pieces of glass under pressure, and in optical contact, will unite perfectly in less than one hour. At the same time the deformation of the outer surfaces caused by the imperfections in the plates compressing them is so very slight that a few strokes on a polishing tool are all that is necessary to restore them to the condition of optical surfaces of high accuracy; or treatment of the surfaces may be altogether unnecessary. It is, perhaps, well in practice to work at a temperature of ten to twenty degrees below this maximum safe temperature in order to insure that no deformation shall occur.

Methods of Distinguishing Between Optical Contact and Complete Union.—With regard to tests for distinguishing perfect union, we have already noted that the optical contact of two surfaces is easily destroyed by sudden temperature change, by the action of liquids, and by mechanical force; when the contact has changed into complete union, they cannot be separated by any of these means, and if force is used the two pieces of glass break as one—not along the interface. A crack or a diamond cut spreads through the two pieces as though one piece of glass, whereas if the pieces are merely in ordinary optical contact, it cannot be made to pass from one to the other.

EXPERIMENTAL.

The temperatures selected for our experiments on the union of glass surfaces were considerably below the annealing-point, in accordance with the facts already discussed. Two preliminary experiments were made, using a metal box having seven-inch sides, filled with sand, and heated by gas burners. Pieces of crown glass 5 × 5 × 1.5 millimeters, were put into contact, wrapped in asbestos wool, and held together by a clamp; they were then heated at the rate of one deg. Cent. per minute to a probable maximum of 400 to 450 deg. Cent., maintained at this temperature for one hour, and slowly cooled.

They were found to have united, but not completely. When torn apart with considerable force each piece carried with it glass from the other. All the surfaces were optically perfect after heating.

In the second experiment larger pieces (one inch diameter, one eighth inch thick) of different kinds of glass were employed—crown and heavy flint. Heating was as before, but rather more vigorous; probable maximum temperature 450 to 500 deg. Cent. The glass was clamped between pieces of brass plate, with asbestos packing. The disks united at one place only; here the joining was perfect, and when they were forced apart the flint carried with it a portion of the crown over the whole of this area. The external surface of the flint glass was spoiled, as it had softened slightly; the crown glass was almost uninjured.

These experiments having proved that joining would take place, more careful ones were conducted with a view to constructing apparatus by the method.

A platinum-wound electric tube furnace (internal dimensions of the oval tube 3½ inches × 2½ inches, 14 inches long) was fitted with double silica windows at each end. It was controlled by two resistances in series. One, the main resistance, was used to compensate for the very great changes in the resistance of platinum which take place between 20 deg. Cent. and 600 deg. Cent.; the second permitted of much more gradual changes of resistance, and formed the fine adjustment in this respect. The temperature at any instant was known by means of a platinum resistance thermometer, allowance being made for any lag in its indications, and, further, the thermometer was connected to a Callendar recorder, giving a permanent record of the temperatures used in any experiment, and enabling the *rate of change* of temperature to be seen at a glance.

The heating and cooling were therefore very completely under control, and a continuous temperature change as small as one quarter deg. Cent. per minute could be maintained indefinitely.

An arrangement by which polarized light could be passed through the furnace, and examined after passing through the piece of glass or silica under test, completed the apparatus. By this means the effect of unequal heating caused by rise or fall of temperature could be observed, and if necessary the actual stresses set up in any part of the test-piece could be calculated at any time during or after the experiment.

Three plates, all of a hard crown glass, were put into optical contact, the center one being about ten millimeters thick, and drilled so as to give a cell suitable for the comparison of two liquids, as in the Rayleigh interference refractometer. The outer plates were, of course, merely windows of about 3 millimeters thickness. The cell was heated without pressure in the electric furnace at the rate of 2 deg. Cent. per minute to 460 deg. Cent., and after two hours at this temperature it was cooled at 4 to 5 deg. Cent. per minute; the arrangement of the furnace permitted continuous inspection of the cell. During heating, at 200 to 300 deg. Cent., minute imperfections in the contact grew rapidly, one side of the cell coming almost completely away. When cold it was found to be out of contact over parts of the surface, the rest of the surface being in contact, but covered in spots.

Rapid temperature changes, such as would easily have separated glass in ordinary contact, had no effect; water also failed to lift the surfaces apart, and when a thin knife-blade was forced in from a corner where the two surfaces were apart, that portion of the window out of contact was broken off without moving the window as a whole. The cell was then compressed in a vise in such a way as to apply large shearing stresses at the interfaces, with the result that corners of the windows out of contact broke away, while the rest in contact remained unchanged.

The spots referred to above were small round areas where the surfaces were just out of contact. Each developed from a minute flaw in the optical contact of the surfaces, and when examined microscopically very minute black particles could be seen in each, and from the system of Newton's rings apparent in them during the heating they appeared to contain a gas at high pressure; by the same means the pressure was observed to diminish slowly after a spot had spread outward to one edge of the cell, and finally (in a later experiment), when the temperature was raised above the annealing-point, the walls of each spot were slightly but definitely blown out, so as to appear convex from

*A paper read before the Faraday Society, December 18th, 1916.

the outside. It therefore appears that the spots are due to the decomposition of minute particles of cellulose from the rag used in cleaning the surfaces; a pressure of many atmospheres can be produced in this way. By careful cleaning it is possible to eliminate them almost entirely. Cells which have comparatively large areas in contact are less free from spots than those in which no point is far from an edge; the gases which would remain permanently enclosed in the former are able to escape from the latter, and the surfaces then go back into complete contact.

The optical surfaces of this cell were found to be perfect and quite unchanged after heating, including the unsupported internal surfaces; we therefore have *optically worked* surfaces in the *interior* of a solid glass cell. It is not well known that ground-glass surfaces act as if they were in compression; thus, a thin plate originally flat and polished on both sides becomes, when finely ground on one side, a concave mirror of long focus on the other. In the case of our cell, the rough surfaces of the drilled holes push up a burr round the edge which is only a few wave-lengths high, but sufficient to prevent complete optical contact. This burr was therefore removed by "retouching" on a polisher, but traces of it evidently remained, and by producing local pressure caused the union to be very complete over its surface. Severe strain was applied by forcing a thin wedge between the two surfaces without breaking this narrow area of complete union. The same effect was also shown by another corner of the same cell which was out of contact after heating and was broken off; the fracture traveled round the edge of the drilled hole instead of passing straight across it.

A second cell was then made of the same glass and pattern, and heated at the rate of 1 to 1½ deg. Cent. per minute to a temperature nearer the annealing-point —523 deg. Cent.—at which it was kept for two hours, then cooled at 4 to 5 deg. Cent. per minute. Pressure was applied by means of a hand screw-clamp. Two brass plates, with surfaces ground flat, and sufficiently thick to eliminate bending (one quarter inch thick), were used to distribute the pressure; a few thicknesses of thin paper were placed between the brass surface and glass surface to take up minute irregularities; the carbonization of the paper did not interfere with its action.

The union of the three components was complete except for a few small spots. They could not be separated by any of the means indicated, and when subjected to severe mechanical strain a portion of the cell broke away, showing the concholdal fracture of a solid glass block. No bending of the fracture occurred at the interfaces, except at one small portion where a spot showed that there was no contact.

The optical surfaces had all remained perfect as regards plastic deformation. The outer surfaces were slightly corroded by the paper ash, and had to be repolished. When examined by means of a Babinet compensator (for the effect on polarized light), very little internal stress was observed, in spite of the unnecessarily rapid cooling; the maximum stress indicated was about 150 pounds per square inch. This amount could easily be decreased, but is already negligible for most purposes.

A third cell of rather different construction showed very few imperfections of contact. Heating was carried out exactly as in the previous case, i. e., at 90 deg. Cent. below the annealing-point. The areas in contact are all narrow, and no point is more than 2½ millimeters from an edge. Any centers of gas pressure developed in the way already described are therefore likely to disappear owing to escape of the gas, and we find, in general, that these narrow areas give the most perfect joining.

The glass of the cell showed very little strain, although no special precautions, such as annealing, were taken. By avoiding temperature differences when putting the components into optical contact, and by subsequent slow cooling from the annealing temperature, all traces of strain can be eliminated.

The internal surfaces of the cell windows were parallel to one second both before and after union. The degree of parallelism remained quite unaltered, and it therefore appears that the accuracy of parallelism is determined only by the initial accuracy of the central component.

Union of Two Different Kinds of Glasses.—The components of the cells described above were all made of one kind of glass, and the joining of different glasses is complicated by at least three factors—differing expansion co-efficients, differing annealing points of the glasses, and the degree of ease with which they will fuse together in the blowpipe flame. The first will certainly cause the surfaces to come apart while the temperature is rising, but if they are under pressure at about thirty pounds per square inch this should not greatly matter, as they will go into contact when the temperature is constant at its highest limit, and they will then join perfectly. Strain will appear owing to different contraction as they cool, now as one piece, but for some purposes it may not matter. Such strain as this cannot be obviated by "annealing." Difference in the annealing-points is the more exacting factor, for unless the annealing-points of the glasses to be joined are fairly close (within perhaps 50 deg. Cent.) the more fusible one will reach its annealing-point before the less fusible reaches a temperature at which it will unite with another glass in any reasonable time. The annealing-points of glasses in common use may differ by 200 deg. Cent. or even 250 deg. Cent., and it is obvious therefore that many pairs of glasses could be selected which would be very difficult or impossible to join; on the other hand, for most purposes suitable glasses can be chosen. With regard to the last factor, it appears that certain kinds of glass which will not fuse together readily in the blowpipe flame will also not unite by the new method.

A Rayleigh cell prepared of hard crown glass with plate-glass windows was heated to a low temperature—400 deg. Cent.—at the rate of 2 to 2½ deg. Cent. per minute and kept at the maximum temperature for one and a half hours. Pressure was not applied. In consequence of this, and also of the different temperature expansion coefficients, they remained in optical contact only over a very small part of the surfaces. When cold, the glass was found to have united in these places in spite of the unnecessarily low temperature. The areas of contact were so small that the windows could be forced off without fracture and they then carried with them glass from the other component. The optical surfaces had not been changed by the heating.

This experiment (as well as that described above) indicated that two glasses of quite widely differing annealing-points could be joined even under unfavorable conditions.

A more severe test was then carried out with an object-glass having curves of the same radius on the common faces of its components. The annealing-points of the two glasses employed (flint and crown glass) differ so widely, it was thought advisable to heat approximately to the annealing temperature of the softer glass. The lenses, in optical contact, were clamped together at the edge at three equidistant points, then heated at 1 to 1½ deg. Cent. per minute to a maximum temperature of 476 deg. Cent. They remained so for one hour and then cooled at 4 deg. Cent. per minute. They were then completely out of contact, except under the three points at which pressure had been applied; in these places there was perfect union. The flint lens had softened to such an extent that slight dents had been made in its surface by the clamp. Both lenses were found to be strained when examined by polarized light. A few spots which had developed in the usual way from minute dust particles had blown out into flat bubbles in the flint glass, indicating that they contained gas under great pressure, as we had already inferred.

It appears, therefore, that the flint and crown glasses commonly used in object-glasses differ too widely in annealing temperatures for successful union. Owing to the large number of factors which limit the nature of the glasses to be employed, this is one of the most difficult cases to which the method has been applied.

Polarimeter Tubes.—A polarimeter tube having windows permanently fixed in position by this method was prepared without difficulty. The tube was of soda-lime glass and the windows of plate-glass; maximum temperature, 470 deg. Cent. The joint was perfect, and in spite of the fact that different glasses were employed the windows showed little strain—the amount was found not sufficient to interfere with measurements of rotation in any way. For many purposes this form of tube should be very convenient, especially in respect of ease of cleaning and freedom from corrosion. As soon as possible we intend to apply this construction to jacketed tubes; they would somewhat resemble the ordinary pattern of glass Liebig condenser, and should, with careful heating, withstand very high temperatures. The nature of the hot circulating liquid would be determined only by the temperature required, and not by the powers of resistance of the cement, as is the case at present.

Union of Fused Silica.—An experiment with component parts of this material showed that there was no essential difference between its behavior and that of glass; the temperature required for union was naturally found to be much higher. The upper limit of temperature to which silica glass apparatus may be heated is determined by its power of devitrifying; this takes place at about 1,200 to 1,300 deg. Cent. (Blackie, *Trans. Faraday Soc.*, 1911, vii., 158; Crookes, *Proc. Roy. Soc.*, 1912, A, 86, 406) and is accompanied by great decrease in mechanical strength. It is obvious that a very small amount of devitrification would be sufficient to spoil silica glass for optical work, especially as it takes place more readily where there is access to the air, i. e., at the surfaces. The highest temperature which we can use is, therefore, somewhat below 1,200 deg. Cent.; fortunately, a preliminary experiment has shown that a still lower temperature will suffice.

The annealing temperature of silica was not determined, as the small temperature expansion coefficient and good heat conductivity rendered it somewhat difficult to produce observable strain by heating, in the small pieces of transparent silica which were available.

Two plates of silica glass $0.75 \times 0.5 \times 0.1$ inch were put into optical contact with the ends of a silica ring 1.0 inch diameter and 0.5 inch long, in order to make a small cell suitable for investigating the ultra-violet absorption spectra of liquids. This was held in a steel clamp, with a few thicknesses of paper inserted between the steel and the silica, and heated to 1,030 deg. Cent. for one hour.

While cooling, contraction of the clamp fractured the cell, but portions of it, examined when cold, were found to have joined. On forcing them apart some of the material of the plate was torn away by that of the ring, and *vice versa;* from the nature of the union we judge that a rather higher temperature, probably in the neighborhood of 1,100 deg. Cent., will be required to give results equal to those attained with glass. The planeness of the silica plates was found to be unchanged.

Industrial Gas Burners of an Improved Type

THE Bunsen burner is an excellent rough-and-ready contrivance for converting a light-giving gas flame into a heating flame; but it is well known that its efficiency is somewhat uncertain, on account of the variability of the mixture, and that better results can be obtained by mixing gas and air in predetermined proportions before passing through the pipes to the burners. If this is done, however, the mixture is explosive; and to prevent its exploding back into the mains it is necessary to cover the mouth of the burner with wire gauze, or with a finely perforated plate.

But even this does not afford complete satisfaction in the course of some investigations into the behavior of flames burning above gauze, Mr. F. S. Sinnatt, of the Manchester, England, Technical School, found that each of the small flames issuing from the meshes of the gauze tended to displace those near to it, so that the flame sprayed out sheaf-fashion. This spraying becomes a source of danger when the gases are under pressure, since, while each flame appears to be burning properly when examined by the eye, yet analysis shows that gas is escaping unconsumed. The flames on certain perforations in the plate burn improperly, and this is especially the case with those perforations near the perimeter.

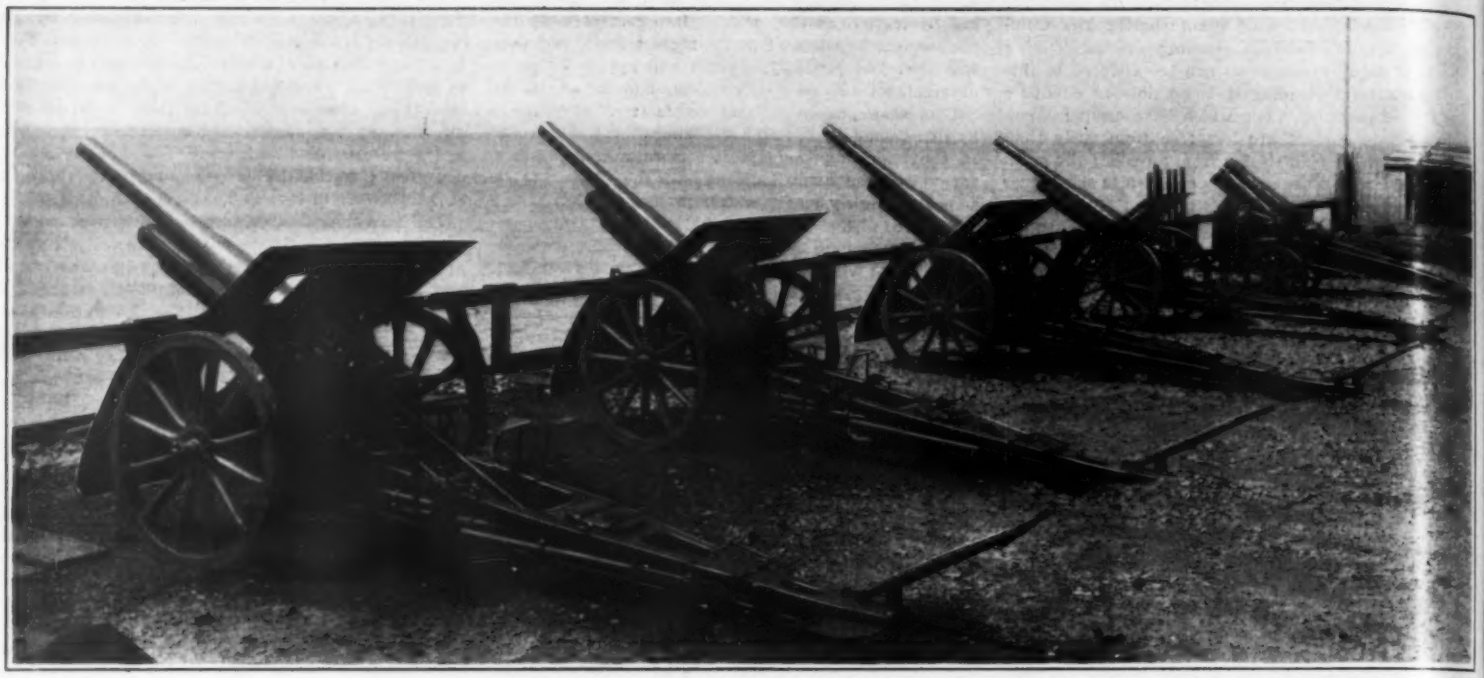
It is further noted that with any variation in the size of the perforations, especially where some became enlarged and others closed with foreign matter, the lengths of the flames on different perforations vary and the surface has peaks which stand out above the remainder of the flame.

In cases where the design of the burners proves to be faulty, and the gas travels down a main and then directly on to the perforated plate, the gas flows through the center perforations faster than through those near the perimeter. The flames therefore project in the center. Consequently, if any of the uneven flames are made to impinge against a cold metal surface, as is frequently the case in the use of these burners, a part might be wholly or partly extinguished with the result that the gas would escape combustion.

To overcome these defects the experiment was tried of making the perforated plate concave, with the object of bringing each minute flame to a common focus at some point above the burners. The result was entirely satisfactory; it proved to be almost impossible for the gas to escape combustion and the effect of variations in the mixture was found negligible within wide limits. The point of focus of the plate may be considered to be the place at which complete combustion will take place, and is, therefore, the point at which the flame should be brought into contact with cold surfaces.

Cooking by Solar Heat

AT the branch of the Smithsonian Astrophysical Observatory on Mount Wilson, much attention has recently been paid to experiments with a solar cooking device, comprising ovens heated by oil under gravity circulation maintained by heat collected by a concave cylindric mirror of about 100 square-feet surface. Definite results have not yet been announced.



A battery of 4-inch field guns ready for trial on the testing grounds

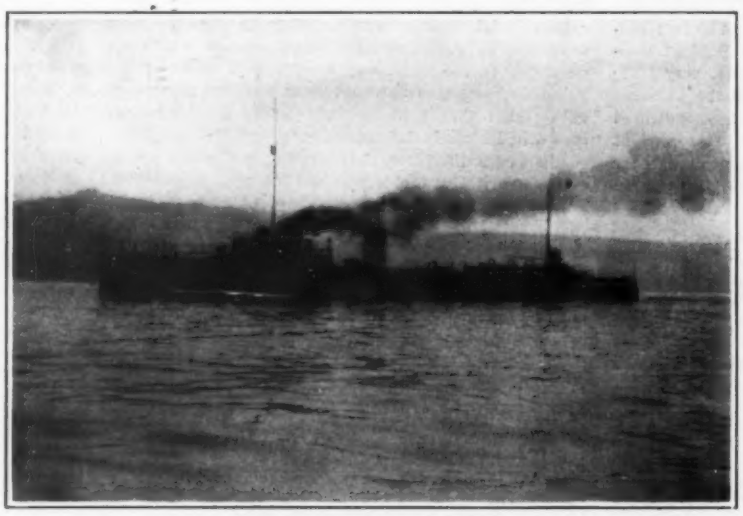
Modern Technical Work in Italy

As Exemplified by One of Its Leading Establishments

When Italy is mentioned in America the first impression that is suggested to the minds of most of us is most likely to be of a land of fine natural scenery; of art, music and grand ruins, in short, a resort of the pleasure seeker and tourist; and this is but natural, for it is to these features that the average traveler devotes his attention, and about them writes his stories, entirely overlooking the practical side of life in this country and its institutions. Of the wonderful engineering features of Italy, both past and present, too little is published, and this applies to our technical as well as our general, literature, and is much to be regretted, for there is much being done in Italy that would be of advantage for us to know. This condition, moreover, is not easily understood, for if we investigate the details of many of the older ruins of Italy, we find that even in the time of ancient Rome the inhabitants of the country displayed unusual ability, not only as architects and builders, but as both civil and mechanical engineers, as is evidenced in the magnificent aqueducts, whose remains still exist, the feats of hydraulic engineering indicated in the great public and private baths, with the pumping and dsitributing machinery connected with them. There are also many other evidences of the ability of the Roman craftsmen as workers in stone, in metals and as builders of ships of no mean size; and if we trace the technical history of the country down to the present day we find that the traditions of the past are fully maintained by the engineers of modern times.

An excellent example of the technical work that is being done in Italy to-day is shown by the establishment of Gio. Ansaldo & Company, which may be rated as not only one of the largest manufacturing companies in that country, but in the world. Its headquarters is in Rome, but its works are in the neighborhood of Genoa. It would be difficult to name anything in the mechanical line that is not or cannot be produced in its great shops, from a battle ship, complete from hull to engines and armament to a locomotive. and the quality of its work has long held a high place in European countries. In the issue of the Supplement for September 16, 1916, there was a picture of a great 15-inch gun that was made in these works, and in the issue of July 8th there is a fine example of the range and versatility of its capacity in the illustrated description of the magnificent passenger steamer, the "Duillo," which was built and fitted by this company. The series of photographs accompanying this article show more fully the character of the Ansaldo works, and some of the things made there.

It would be impossible to give a complete description of these great shops, and what is made in them, in these columns, so only a brief outline will be attempted. The first shop, from which the present great enterprise sprang, was established in 1846 at Sampierdarena and about one hundred hands were then employed, while to-day the roll of workmen numbers 35,000. One of the important products of the early days was locomotives, the first of which were turned out in 1854; and although seriously handicapped by the cost of materials, as practically no iron was made in Italy at that time, and most of the supplies had to be imported at high costs. Later the building of iron ships, artillery and projectiles was undertaken, and the natural evolution of this line of work lead naturally to the building of naval vessels, together with everything required, including armor plate, steam engines and turbines, and later to Diessel and other internal combustion engines suitable for destroyers, submarine craft and all kinds of commercial vessels. This necessitated the establishment of foundries, furnaces and forging and rolling mill shops for the production of the various kinds of steels required, and the fashioning of large parts of heavy machinery, together with boilers of every description. Another branch of work undertaken was the building of electrical machinery of many kinds.



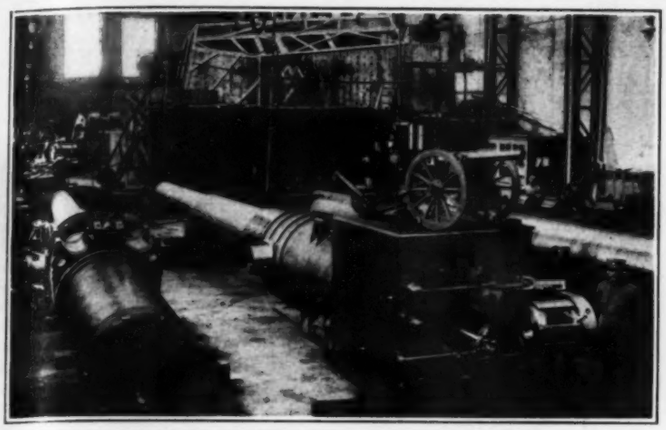
Royal scout boat "Mirabello"

The Ansaldo establishment comprises four separate plants, all located in the neighborhood of Genoa. At Sampierdarena, a suburb of Genoa, are located the shops where marine turbines, locomotives, steam and Diesel engines for marine and electric stations are built, as well as steam boilers of many kinds and ordnance of every description. At Cornigliano Ligure are located the steel works, rolling mills and forges which include iron and steel founderies, steel furnaces, both for the making and heat treatment of steel. Some of the great forging presses for the working of armor plate, big guns and heavy parts of machinery are shown in our illustrations. These shops also contain heavy machine tools used for finishing heavy parts, and factories for the production of all kinds of electrical machinery. The extensive physical and chemical laboratories of the company are located here. The ship building plant is at Sestri Ponente where there are a number of slips where ships up to 990 feet long can be built. Some of these slips are built of masonry, which was made by the fact that a main railway line runs through the property of the company, and several of the longer slips span the tracks. For the building of torpedo boats a special shop is provided, where the craft can be constructed under cover; and throughout the yards are a liberal number of large electric ship-building cranes to serve the slips, together with all the necessary shops and furnaces for building the largest ships of every description. The fitting out yards for ships are at Genoa, where there are spacious wharves alongside which vessels can lie while receiving their finishing touches, adjacent to which are spacious stores and the shops appertaining to the work in hand. There are also several dry docks here, and general repairs to vessels are made at this place. A noticeable feature of this plant are the big floating cranes used for placing engines. boilers and heavy guns in the ships alongside the docks. One of these has a capacity of 150 tons, and is electrically driven. This is convenient for placing armor plate, turbines and big guns, and it has a sufficient lift to handle tall masts. There are other similar cranes of 120- and 60-ton capacity.

There are many other large and important engineering works in Italy, but the one that forms the subject of this sketch is an excellent example of the manufacturing enterprises of that country. Of course these works have taken an active part in the work of producing munitions for the war, and its widely varied capacity has been of inestimable value. It is a fine example of practical preparedness.

Monazite in Ceylon

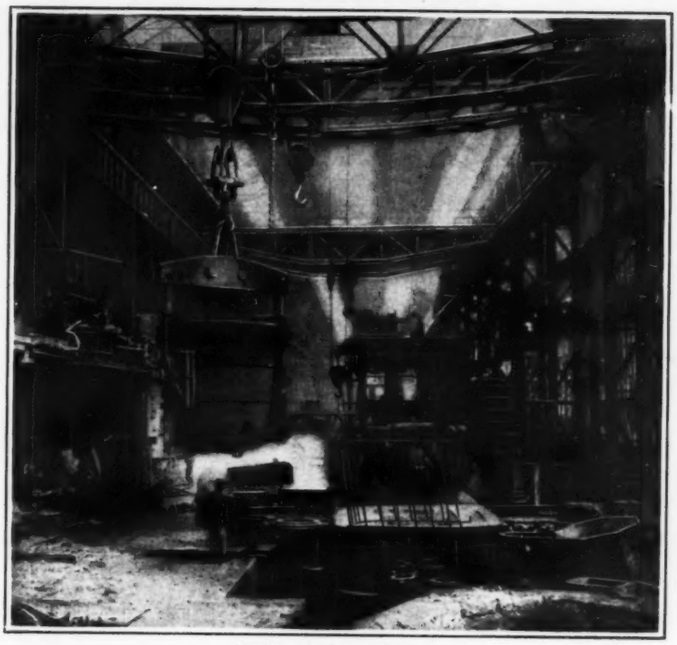
A consular report from Ceylon announces that substantial deposits of monazite have been discovered in that island, and that a start has been made in working the deposits at three points. Monazite is valuable; it contains thorium, which is used in the manufacture of gas mantels.



Extremes meet. A 3-inch gun standing upon a 15-inch gun

A 15,000-ton forging press at Ansaldo's

One of the most powerful forging presses in the works

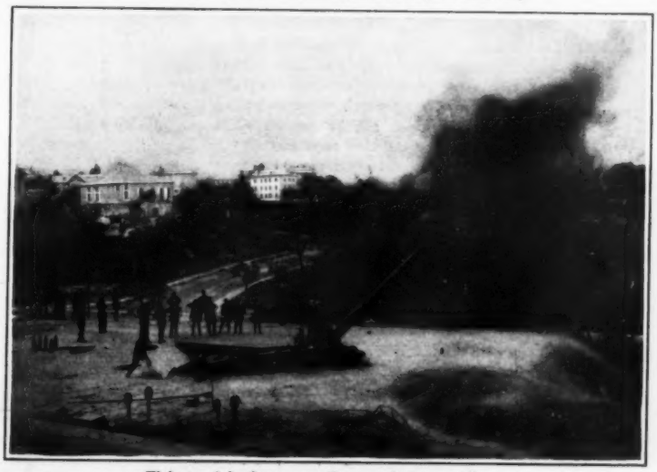


Casting steel gun elements

One of the Ansaldo small and medium gun shops

Small and medium size guns ready for delivery

A 4-inch gun mounted on a motor car, accompanied by its train



Firing a 6-inch gun on the proving grounds

Capillary and Electrocapillary Chemistry—II*

A Survey of the More Important Phenomenon, and Technical Applications

By W. C. McC. Lewis, M.A., A.Sc., University of Liverpool

Concluded from SCIENTIFIC AMERICAN SUPPLEMENT No. 2145, page 91, February 10, 1917

(c) TECHNICAL APPLICATIONS OF ADSORPTION.

Technical processes in which adsorption plays an essential part are very numerous. In the place of first importance one should mention *dyeing* processes. It is now fairly generally recognized that the first stage in such processes is a true adsorptive one. Dyestuffs are generally characterized by exerting a very marked lowering effect upon surface and interfacial tension. It follows, therefore, from Gibbs' principle that they are largely adsorbed, with the result that in the surface layer (which probably does not exceed 10^{-6} centimeters in thickness) the concentration of the dye becomes great, eventually exceeding the limit of solubility which it possesses in the ordinary sense. The result is that precipitation or coagulation takes place and this in many cases is accompanied or succeeded by ordinary chemical combination with certain of the amphoteric substances present in the material to be dyed. It is clear, of course, that adsorption cannot cover the whole phenomenon, for adsorption in the sense of Gibbs' theory is a reversible process, while dyeing is essentially an irreversible process, the fastness of the dye being dependent upon the fact of irreversibility. In the case of *tanning* the process is very similar. A reference will be made to tanning later from the standpoint of electro-osmosis. It will be observed that in dyeing and tanning we are dealing primarily with the adsorption of colloidal matter upon a surface, most dyestuffs such as Congo red belonging to the group of so-called "electrolytic colloids," that is the colloidal part functions as an ion (anion), *Bleaching processes*, while being fundamentally adsorptive in nature, differ from the preceding cases in that the bleaching agent is not usually a colloid and therefore its effect upon the surface is a better defined chemical process. A bleaching agent such as sodium hypochlorite lowers the surface tension of water and hence is positively adsorbed at the surface.

Surface adsorption of molecules and ions of electrolytes plays a fundamental *rôle* in *agricultural problems*. One of the results so far obtained in this very complex subject is the conclusion that the general character of a soil is as much governed by the size of grain, that is, by the surface area of the soil particles, as by their chemical nature. Heavy clay means small porosity and therefore small surface and small adsorbing power for salts and non-electrolytes dissolved in the water present. The result is that this material is unsatisfactory. The function of adsorption in soils is to retain the soluble salts from being washed away too far from the surface of the ground during heavy rain. The extent to which adsorption occurs depends not only upon the soil but also upon the nature of the fertilizer. The question of the efficiency of fertilizers would lead us too far, but that the problem is fast becoming an exact applied science is very evident. It is clear on general grounds that capillary chemistry plays a great *rôle* in such problems, as we have already seen in connection with the theory of wetting, but it is to be feared that many of the workers in this field have not fully realized the significance of capillarity for the processes concerned.

A further important technical application of adsorption is found in the methods of *water* and *sewage purification* in so far as *filtration* is concerned. The functions of porous substances, such as charcoal and sand, are so familiar that they need not be considered at length. It is sufficient to point out that capillary adsorption is the fundamental factor, though, as in dyeing and tanning, the irreversibility of the process is an essential; and in so far as irreversibility exists the phenomenon is not covered by the simple capillary theory. Purification problems also come under the head of coagulation of colloids and a brief reference to them will be made there.

Another field in which adsorption plays a part is that of the *cleansing action of soap* and the *clarification of liquids* such as wines. In the case of soap there is no doubt that the alkali produced as a result of hydrolysis acts as a peptonizer or emulsifier for the fatty matter which is to be removed, and the intimate contact, which is necessary to attain this, is possibly brought about by the fact that the soap, both unhydrolyzed and as colloid ions, depresses the interfacial tension with the result that adsorption of the soap takes place and capillary wetting occurs easily. In the case of clarification processes the results of a particular investigation may be cited as illustrative, the object being to find a good clarifying agent for certain wines which would be effective without altering the taste appreciably. According to F. La Marca (see this journal, 1915, p. 1006), "experiments with nine types of Italian wines indicated that fish glue was the best clarifying agent." The tannin and extract content can be reduced by adsorption upon the fish glue without altering other constituents. "Egg albumen is also an excellent clarifier and does not alter the composition of the wine." "Aluminous earth markedly reduces the acid content and also the extract but not the color of the tannin." "Acidity and color are diminished by charcoal which also reduces the tannin to a slight extent." The *specific* effects of adsorption upon surfaces of different nature manifest themselves here very clearly.

(d) APPLICATION OF COAGULATION PRINCIPLES.

Coagulation, as already pointed out, is brought about by removing the electric charges which are situated upon the colloid or emulsion particles and which go to maintain these in a stable sol form. The discharging process is most conveniently carried out by means of electrolytic ions of opposite sign to that possessed by the colloid. The colloid may also be discharged by being carried to an electrode, the discharge at the electrode being presumably quite analogous to the discharge of an ion in ordinary electrolysis. It is of some interest to consider one or two large scale applications of both of these methods of producing coagulation. First of all, coagulation by ions.

A very important application of this is found in one of the methods employed for rectification of current, that is the transformation of alternating into direct current. In this connection the *aluminium rectifier* is well known. A condenser is placed in the alternating current line, one plate of the condenser being of aluminium, the space between the plates being filled with an aqueous solution of a salt. On the aluminium plate there is rapidly formed some colloidal aluminium hydroxide and if this can be made to coagulate and adhere to the plate the current taken off will be unidirectional. The problem is, therefore, to choose an electrolyte which will most completely effect the coagulation of the colloid. Since aluminium hydroxide is a positively charged colloid the discharging effect must be brought about by an anion, and further as we have seen the higher the valency of the ion the more effective it will be. Thus the salts of monovalent acids, such as nitrates, chlorides, acetates, etc., are inefficient. Salts of divalent acids such as sulphates, carbonates and tartrates, are moderately efficient. That is to say, a rectifier containing such divalent salts will rectify current whose voltage does not exceed 30 to 50 volts. If the current is at a higher voltage the rectification is only very partial and incomplete. Using trivalent radicles such as phosphates, citrates, or borates, the efficiency of the rectifier is much increased as it is now capable of dealing with a pressure of over 200 volts. It is interesting to note also that silicates, though strictly speaking belonging to a divalent acid, are exceedingly efficient, no doubt due to the fact that the coagulant is here itself functioning as a colloidal anion though a clear explanation of the mechanism is wanting. Obviously, much investigation remains to be done. It would be interesting to try other colloidal anions of much greater complexity than colloidal silicate, such, for example, as organic electrolytic colloids, like Congo red. The point as to whether the molecular mass of the coagulant is significant as well as its valency also requires investigation.

Another important application of coagulation is met with in the *de-emulsification of water* contaminated with oil, the oil being in the form of an emulsion. It is an important engineering problem especially in connection with the forced lubrication in steam turbines, and has been solved with some considerable success by the use of alum. The oil particles are negatively charged and can, therefore, be discharged by a cation of high valency such as Al···. The alum solution is run slowly into the emulsion, the oil coagulates on the top and may be run off. The result is that a considerable quantity of oil is recovered which would otherwise have run to waste and at the same time the oil is prevented from fouling the heated parts of the engine. It may be remarked that oils, otherwise very similar, differ much in the ease with which they become emulsified (cf., for example, A. Philip, this journal, 1915, 34, 697).

The next problem to be touched upon is *river sludge* formation and *sewage precipitation*. The fact that material which remains in suspension as long as the liquid medium is fresh water but is deposited when carried to the mouth of a river where the medium is now salt, obviously suggests that coagulation has been brought about by the sodium and calcium salts of the sea water. When this process goes on for centuries formation of deltas results. As a rule coagulation of this kind is anything but desirable. In other cases, however, notably when a river overflows its banks, the result may be beneficial. The fertility of the Nile valley, for example, may be ascribed to this cause, the rich colloidal matter in the river water being precipitated upon the adjacent soil. In view of the large amount of sewage annually carried down by rivers the question has been raised as to whether it may be possible to recover by means of regulated coagulation some of the valuable fertilizing materials represented by the phosphorus, nitrogen, and potassium contained in the sewage. As a matter of fact, an attempt has been made along these lines in Germany, but so far the efficiency is low. It is nevertheless a very important problem. Our present practice of getting rid of sewage somehow can scarcely be the last word on the subject.

As a final illustration of coagulation by chemical means, that is by ions or even by change in the nature of the solvent by large addition of non-electrolyte, a reference may be made to one or two methods for the *coagulation of rubber latex*. A method suggested by Fulton and Macallum (Eng. Pat. 9066 of 1914) depends as far as I see upon the change in the nature of the medium. The latex suspended in water is treated with aldehydes or ketones other than formaldehyde. As an example, eighty to ninety parts of water are added to ten to twenty parts of aldehyde or ketone and the solution may be used with about half its volume of latex, which is preferably sprayed over the coagulant. An alternative method of treatment which causes coagulation and at the same time sterilizes the rubber is that proposed by S. C. Davidson (Eng. Pat. 22,138 of 1914). A solution of one part of sodium thiosulphate in sixteen parts "alkalized cresol," that is a solution of creslyic acid in aqueous sodium or potassium hydroxide, is stirred into Hevea latex in the proportion of one to five per cent. The latex is allowed to stand for twenty-four hours and is then coagulated by means of a one to two per cent solution of sulphuric acid. Other acids, such as acetic, trichloracetic, or hydrochloric, may be used. The SO_2 evolved on addition of the coagulating acid possesses a preservative effect upon the rubber. It is somewhat obscure why it should be necessary to allow the latex to remain so long in contact with the thiosulphate. The thiosulphuric acid may, of course, exert an incipient coagulating action or it may be that the thiosulphate requires this time to take the place of other salts already adsorbed upon the latex particles. That is to say, it may be a case of preferential or selective adsorption. I have no idea as to how efficient this actual process may be. It serves, however, to indicate how much purely scientific work remains to be done in order to supply us with a larger number of general principles which would serve as guides in this or other colloid problems.

Let us turn now to the alternative method of colloid coagulation by bringing the colloid directly into contact with an oppositely charged metal electrode. This has had up to the present less utility than the ionic method. De-emulsification may be easily effected upon the laboratory scale, but I do not know if it would compare with the alum method on the large scale. The method, however, has been employed for sewage treatment. According to A. M. Williamson (*Trans.* Amer. Electrochem. Soc., 1915, 27, 193) an installation in

*Journal of the Society of Chemical Industry.

America deals with as much as a million gallons of sewage per day. On general grounds one would think that the electrical method should be efficient in that all the colloidal material would automatically separate itself at both electrodes according to the sign of the charge. The method would, however, be more economic of current the smaller the content of electrolytic salts present.

(E) SELECTIVE ADSORPTION.

This principle has been made use of in a method proposed for the *separation of radioactive salts* (Ges. für Elektro-Osmose, Eng. Pat. 10,083 of 1914). The salts are in a state of adsorption upon colloid material, this condition being the result of a preliminary treatment. The point is to remove the adsorbed radium salts as completely as possible from the colloid material and from other salts, e. g., barium. This is effected by adding to the colloidal solution certain other salts at suitable concentration. These salts are preferentially taken up by the colloid, the radium salt thus passing into solution. By way of illustration, a MnO_2 adsorption product of Ra and Ba in a fine state of subdivision is boiled with NH_4Cl solution of certain strength and the solution filtered. On analysis it is found that the solid matter contains 32.7 per cent of the Ba and 64.7 per cent of the Ra originally present. That is, a certain amount of separation of Ra and Ba has been effected. Although a single run leads only to a partial separation the method is interesting and suggestive.

(F) APPLICATION OF THE "PROTECTIVE" EFFECT.

Reference has already been made to the protective and preservative action of gelatin upon colloidal platinum. In a process patented by the Gesellschaft für Elektro-Osmose (Eng. Pat. 9261 of 1914), the object of which is to *prepare stable colloidal solutions of metals* in general, use is made of *colloidal silicic acid* as the protective colloid. The silicic acid is obtained in a pure state by a method which will be referred to later. As an example of the procedure adopted, a metal salt, i. e., a silver or gold salt, is reduced by a suitable reagent such as hydrazine hydrate in presence of the silicic acid. A stable solution of silver or gold results, which is purified from the electrolytes by electrolysis. In a later patent (Eng. Pat. 15,267 of 1914) it is claimed that the protective effect of silicic acid can be extended to the preparation of stable metals prepared by Bredig's sparking method, the instance quoted being nickel. Further applications of the salt-reduction method is presence of silicic acid deal with the preparation of colloidal selenium, palladium and platinum. It would appear, therefore, that the method is a fairly general one. A further instance of protective effect is to be found in a process for *sizing and coloring parchment paper* (E. Fues, Eng. Pat. 19,816 of 1914). A solution which contains both an acid and a basic dyestuff may in general be regarded as an unstable one. In the presence of some size, however, precipitation can be prevented, the size acting as a protective colloid. The mixture of dyestuffs can therefore be successfully applied, in this case, to the paper.

(G) APPLICATIONS OF ELECTRO-OSMOSIS.

This is one of the most important branches of applied electro-capillary chemistry. As an example of a general type of problem to which electro-osmosis is applicable one may instance *filter press* work. In this connection F. Ulser (*Z. angew. Chem.*, 1915, 28, 1, 308) describes a process whereby filtration of liquids containing very fine particles can be made without clogging the filter cloth. The filter is of the usual form, consisting of a number of chambers in each of which electrodes are placed. The chambers are first filled with liquid, the current is passed, and the suspended matter wanders to one or other of the electrodes, becomes electrically discharged, and is deposited. The liquid can now be made to pass with relative ease through the filter cloth. Clogging of the latter is thus largely diminished, and hence excessive pressure is not required. The author claims that the method separates the finest particles from liquids and can be used for mineral colors, dyestuffs, barium sulphate, and other suspensions. Strictly speaking, the process is an illustration of cataphoresis and coagulation rather than electro-osmosis, but the arrangement is very similar to that employed in electro-osmotic problems generally. A second instance is the application of electro-osmosis to the preparation of pure colloids, the case in point being the preparation of *colloidal silicic acid* of low molecular weight, that is, in a state of fine subdivision (Ges. für Elektro-Osmose, Eng. Pat. 9273 of 1914). To begin with, an alkali silicate solution of five to ten per cent strength is placed in an anode compartment, the electrodes being preferably perforated. When the product is to be used medically the anode consists of platinum gauze. Brass wire net serves as the cathode, the electrodes being separated by an electrically neutral membrane, consisting of carborundum and corundum. The process begins with low voltage, which is ultimately raised to sixty to seventy volts to remove all the alkali from the compartment. The colloidal silicic acid negatively charged,[2] is precipitated at the anode, the sodium leaving the compartment. Traces of foreign acids present with the silica are removed by transferring the solution to a vessel serving as a cathode and electrolyzing, the anode being surrounded by parchment.

A further illustration of the applicability of electro-osmosis deals with the *tanning of hides* and *impregnation of similar materials*. In the usual method of tanning, the material is brought into contact with the tanning liquid under suitable conditions of concentration and temperature, and allowed to remain in contact for a length of time. In the present process (Ges. für Elektro-Osmose, Eng. Pat. 19,849 of 1914) the tanning action is accelerated and possibly improved by bringing the tanning colloid into very close contact with the hide by electrical means. The hide is kept at a suitable potential, positive or negative, and the tanning substance, which is naturally charged, moves up to and is discharged upon the surface. A few details are given in the abstract (this journal, 1915, 34, 1021), and are as follows:

"Hide is tanned by electro-osmosis by utilizing the material to be treated as a partition, without fitting it tightly to the walls, to divide the space beween suitable diaphragms, the latter being so selected that the active constituents cannot migrate through them, whereas substances affecting the osmotic action unfavorably pass through and are separated from the liquid. Constituents which hinder or delay the process are removed from the hides or skins electro-osmotically by desorption before the actual tanning. During treatment the hides or skins are caused to acquire automatically a potential suitable for the tanning substances used; with tannin this must be of an electro-positive character, with chromium compounds, electro-negative."

As a final example of electro-osmosis we may briefly consider the manufacture of *gelatin for photographic emulsions* (Ges. für Elektro-Osmose, Eng. Pats. 21,448 and 21,484 of 1914). The object is to get a gelatin free from fat and from mineral and reducing constituents. The procedure is as follows: A solution of gelatin enclosed between electrically indifferent diaphragms is subjected to an external voltage. The inorganic ions migrate through the diaphragms in the ordinary way and so are removed. At the same time any albuminoid bodies are coagulated and can be mechanically separated off. The resulting gelatin is thus free from turbidity which sometimes manifests itself, owing to the presence of albumin. Exactly the same procedure is applicable to the manufacture of *high grade glue*. Modifications may be introduced in the form of electrically charged diaphragms for the separation of other constituents, thereby yielding a very pure product.

From the survey given above, it is evident that the subject of capillary and electro-capillary chemistry is one of great magnitude and importance both from the scientific and from the technical aspects. In the present situation it is plain that technical application has considerably outrun theory, and if future industrial development is not simply to be on empirical lines, it is essential that scientific investigation must be greatly accelerated. At the present time capillary chemistry does not occupy the place it should in our University curricula. But as things stand it is impossible to deal with the subject effectively. From the manufacturers' standpoint, a serious lesson might be drawn from the activities of a single German firm, the Gesellschaft für Elektro-Osmose, from whose patents several illustrative examples have been taken. It is fairly evident that such processes can only be dealt with and extended by proper scientific control. It has been repeated *ad nauseam* that this is the only way to advance not only in regard to the applications of capillary chemistry, but in all applied chemistry. It does not, however, appear, even yet, to have been sufficiently realized.

[2] It is not quite clear what sign the charge possesses under these circumstances. Usually SiO_2 *sol* is negative, but becomes positive in acid solution.

Fennel and Its Uses

FENNEL, *Fæniculum vulgare* of botanists, has long been recognized, more especially in Europe, as a plant of considerable importance in an economic point of view. Its supposed medicinal qualities were evidently known at an early period, for its uses, both for flavoring of food and for medicine, were recorded as early as the tenth century. The cultivation of fennel as a crop was first stimulated in Germany by Charlemagne, who directed it to be grown on the imperial farm. Its cultivation in Spain dates back to 961. From that time on the cultivation and use of fennel has steadily increased and is held in high esteem for food and medicine.

The fennel plant is a member of the carrot family and is closely related to dill, celery and parsley. Its stems attain a height of five or six feet, and are furnished with rather large leaves that are much divided into a vast number of fine, slender segments of a deep bluish green color. The flowers are arranged at the top of the branches as in the wild carrot and are small and yellow. The fruits, which are known in the trade as fennel "seeds," are small, rarely one fourth of an inch in length, and are yellowish or dark colored, striated and of a sharp acrid or sweetish taste. They have an agreeable aromatic odor.

Fennel is a native of central Europe, where it is now largely cultivated. The regions of its best development are Saxony, Franconia and Wurtemburg. It is grown commercially also in the south of France near Nimes, and in Italy. Variegated forms of the fennel plant are cultivated in Japan, China, India, southern Russia, Greece and in northern Africa. It has been introduced and is now growing wild in England and in the United States. It is natural that a plant growing under such a wide variation of soil and climate varies greatly in stature, foliage, and in the size and form of the seed, but it may be accepted that all the forms belong apparently to a single species.

Notwithstanding the circumstance that fennel has been cultivated long and extensively in the East as well as on continental Europe, yet it has hitherto been neglected almost entirely in our own country, where practical agriculture has advanced very rapidly in recent years. Up to the present time fennel, like its near allies, cumin, anise, and caraway, has continued on the list of agricultural plants of no more importance than of forming an object of curiosity in the botanical gardens or the agricultural museum, and it may be said that its presence even in such places as these has been rare.

This valuable crop should be brought before the notice of the American farmers, with the hope that the farmers may be induced to cultivate successfully this staple article of produce in various parts of this country. That it is suitable for our climate there can be no doubt, from the success which has attended the cultivation of this crop in Europe. It should demand the special attention of the small farmer in the South who is seeking diversification of crops. From observations made in this country and in Europe, fennel thrives on loose, sandy soils where most other crops will not grow successfully. Being more or less independent of drought, the plants grow vigorously and yield a fairly large crop, and do not exhaust the soil like the corn crop. It prefers high, sunny situations, and under such conditions yields about 1,000 pounds of seeds (fruits) per acre. If the farmer in the South can grow cotton advantageously during normal times, how much more profitable would it be to grow fennel, which is now selling for 20 cents a pound. The average importation of fennel into the United States during a normal year amounts to about 250,000 pounds.

Although fennel is cultivated in gardens for the sake of its leaves, which are strongly aromatic and are used in fish sauces, the part of the plant of prime importance is the fruit, which is employed far more extensively in this country than is generally recognized by the man in the street. The fruit of common or sweet fennel is recognized by the pharmacopeias of practically all countries and is commonly used both in medicine and for culinary purposes. Fennel is said to be stomachic and carminative and large quantities are used annually as a household remedy for a variety of ailments peculiar to children. It is said to be excellent in the colic and is used externally with success in poultices to swellings.

Besides its employment in medicine, fennel has other domestic uses which must not be overlooked. Certain classes of our foreign population use fennel either in the ground or whole state in their bread and meats. Perhaps the bulk of the fennel seed imported is ground into a fine powder and used as an ingredient in cattle food. It is employed also in the manufacture of cordials.

Fennel fruits contain two oils; one is an essential or volatile oil to which is due the pleasant aromatic odor of the seed, and the other is the mild and tasteless which is extracted and used. The amount of volatile oil present varies from 2 to 6 per cent. It is used for a great variety of purposes, chief of which are for flavoring liquors, medicines, and for mixing with other oils for perfumery.

The Phototropic Sense in Plants

Apparently Intelligent Directing Function that Leads them to Seek Light

THE distinguished French Academician, Edmond Perrier, recently remarked in an article in the *Army Bulletin* that periods of inaction at the front frequently afford admirable opportunity for field work in the natural sciences. A French scientist who has for some years been investigating light phenomena, M. Miramond de Laroquette, has been recently utilizing such opportunities for studying phototropism in plants and gives an interesting account of his investigations in a late number of *La Nature* (Paris). M. de Laroquette has been peculiarly interested previously in the curative effects of light. Thus he published an article on his experiments with colored lights in *Paris Médical* in July, 1912, and one on the absorption of solar rays in the *Bulletin* of the Society of Exotic Pathology in May, 1914. In regard to his recent work he writes as follows:

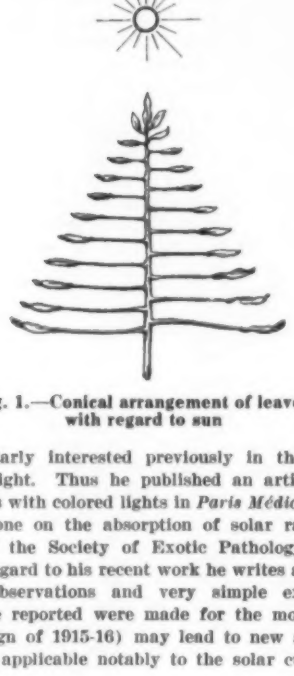


Fig. 1.—Conical arrangement of leaves with regard to sun

"Daily observations and very simple experiments (those here reported were made for the most part in the campaign of 1915-16) may lead to new and useful knowledge, applicable notably to the solar cure, which is such an efficacious means for the cure of the diseased and of the wounded.

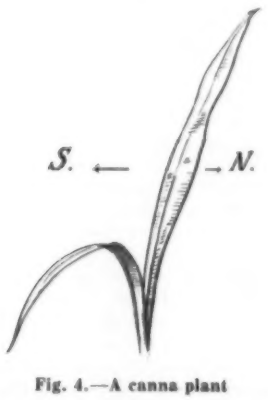


Fig. 4.—A canna plant

"The plants derive a great part of their energy from solar radiation and probably for this reason tend to seek as large a place in the sun as possible. It spreads a surface of delicate green leaves (green absorbs almost as much light as does black) which is extraordinarily large in relation to its total mass.

"Take, for example, a fig tree 3 to 5 meters high; it has about 2,150 leaves, comprising a surface of about 49 square meters for a weight of 17 kilogrammes of foliage. About a third of this surface is bathed in direct solar light, the remainder in diffused light. The leaves taper and expose their upper varnished surface, which is the greenest, to the light. From experiments made by me and published in May, 1914, I was able to calculate that this fig tree absorbed in a single day of summer more than 40,000 large calories of solar radiation. The greater part of this energy (i. e., 32,000 calories) is expended in evaporation of about 45 liters of water, which excites in the roots a proportionate suction of water charged with salts. The rest probably serves for the performance of vital functions, for the statics of the plant and the elaboration of its living substance and its reserves.

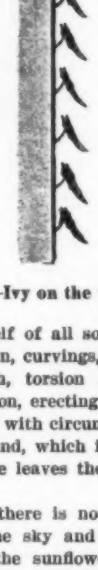


Fig. 3.—Ivy on the wall

"The plant avails itself of all sorts of processes for exposing itself to the sun, curvings, regular or unequal lengthening and growth, torsion or rotation of the stalks and petioles, flexion, erecting of the limbs, movements variable in accord with circumstances, but always adapted to the desired end, which is to absorb through the upper surface of the leaves the possible maximum of radiation.

"In the open air, if there is no obstacle, the plant orients itself toward the sky and toward the south; certain ones, such as the sunflower, even follow the sun in its daily movements. If the lighting is unilateral the plant always turns toward the side from whence the most light comes, whatever the orientation of this side may be; it knows in precisely what measure to curve itself, erect itself, revolve or lengthen itself. There is in the *ensemble* of the leaves of a single plant, and also, it would seem, in plants of the same species living on the same terrain, a manifest co-ordination which appears to correspond to a common will, with the intent to achieve the best total yield. There is even, it would seem, in certain cases, an apparent respect for acquired situations.

"Most trees and shrubs tend to take a conical or a hemispherical form by means of a measured lengthening of stems and branches, thus giving the leaves the best opportunity to expose themselves to the sun (Figs. 1 and 2). The ivy extends itself along the ground or scales walls and arranges its overlapping leaves in such a manner that each leaf has as much light as possible without shadowing its neighbors (Fig. 3). Observe the canna in Fig. 4, with its two long and wide leaves oriented north and south. The north leaf erects itself vertically and exposes to the south its upper varnished surface; the south leaf if similarly erected would both face the north and interfere with its sister leaf; it avoids this double peril by curving downward and inclining itself toward the sun. Upon the pond the leaves of the water lily divide the available surface; the oldest lie flat, absorbing air, water, and sun, all at the same time; the younger leaves are still immersed, or they rise, when the space is taken up, between two old leaves and remain half closed above the water in a position which reduces the shade cast (Fig. 5).

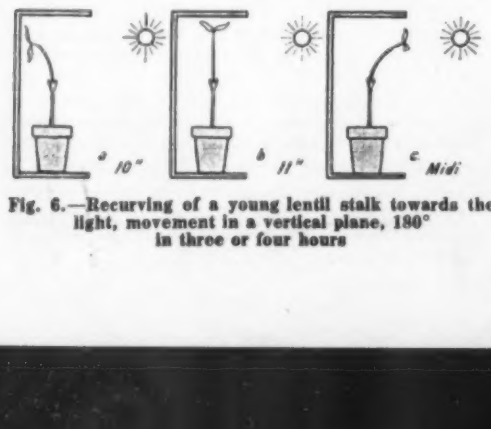


Fig. 6.—Recurving of a young lentil stalk towards the light, movement in a vertical plane, 180° in three or four hours

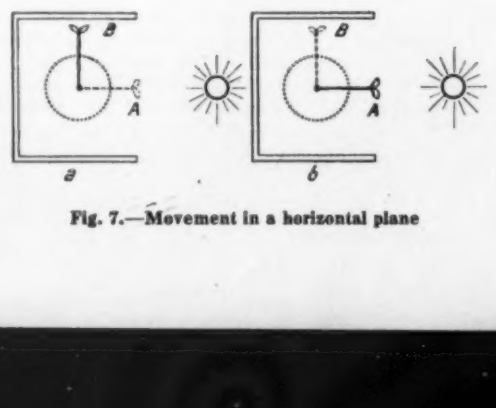


Fig. 7.—Movement in a horizontal plane

"The sense, or, if you please, the phototropic *instinct* of plants, visible in their natural attitudes, is evidenced still more strongly in the conditions of experiments which oblige them to displace themselves, and to make movements which are comparatively extended and rapid under our very eyes in order to achieve their ends.

"Let us sow some lentils in a box closed at the top and open on a single side. From the moment the young stalks emerge from the earth they will turn toward the lighted side; they curve themselves in such wise as to be *parallel* to the rays of light, while the leaves so dispose themselves as to be perpendicular to it. At night the young stalks erect themselves, but as soon as day comes they again curve toward the light. Place in the box a young lentil plant which has grown erect in the open air; immediately it curves toward the lighted side, and within an hour or two attains a right angle. Turn it toward the back of the box (Fig. 6) and the stalk will immediately begin to erect itself, then curve in the opposite direction; in an hour it is erect; in two or three hours it has acquired the new curve toward the light. In the course of from 120 to 150 minutes the top of the stalk has moved from 150 degrees to 180 degrees in a vertical plane.

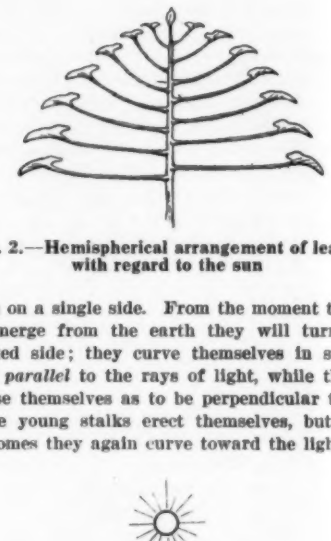


Fig. 2.—Hemispherical arrangement of leaves with regard to the sun

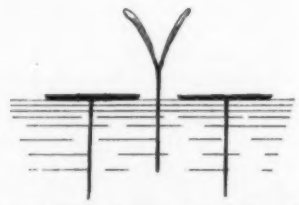


Fig. 5.—Three leaves of the water lilly

"Now turn the pot 90 degrees only (Fig. 7), so the top of the stalk is toward one of the sides of the box; the plant this time will not erect itself; its upper extremity remains horizontal, and without curving forward it will turn toward the light by a movement of *rotation* in a horizontal plane upon the lower part of the stalk, which acts as a pivot; it thus takes the shortest road to return to the light.

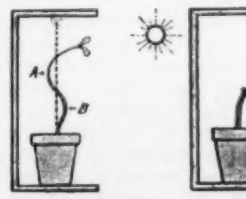


Fig. 8.—Double curvature of a stalk: A, Phototropic curvature; B, curvature of compensation

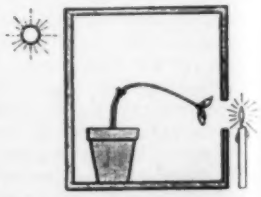


Fig. 9.—Curving towards a candle in a dark chamber

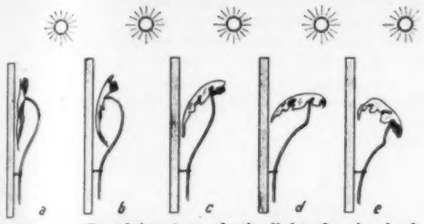


Fig. 10.—Revolving towards the light of a vine leaf fastened to the wall in the evening

"Stalks usually effect their phototropic movements and curves in their upper portion, the lower portion remaining vertical when the stalk is short and stiff; but when it is long and slender it often produces an inverse curve in this lower portion, a *curve of compensation* which permits the plant to resist the weight thrown to one side (Fig. 8).

"The leaves are oriented toward the light by the motor organ of leaves (notably of sensitive leaves), plays only a very limited *rôle* in these phototropic movements; moreover all the flexible parts of plants appear to be capable of movement.

"Flowers also obey the heliotropic law and try to receive the light normally, and usually on their upper faces. They also taper, spread themselves, lift themselves on their stalk, lean over or straighten up toward the light. Like leaves, if they are turned away from the light, they make extended and relatively rapid movements to regain it.

"A flower fastened with the head down by a thread (Fig. 18) erects itself by curving the stalk.[2] The movement is easy and rapid if the fastening is at a certain distance from the flower, slower and sometimes incomplete if exactly at the base.

"A more difficult feat for the flower, and one which shows its skill and the complexity of its effort, is shown in Fig. 19. Cover half or two thirds of a rinia flower with a suitable hood of black paper, not too closely attached; in a few days the flower will free itself.

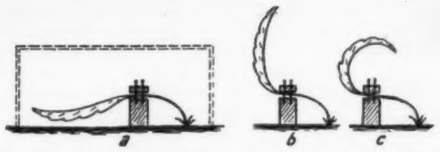
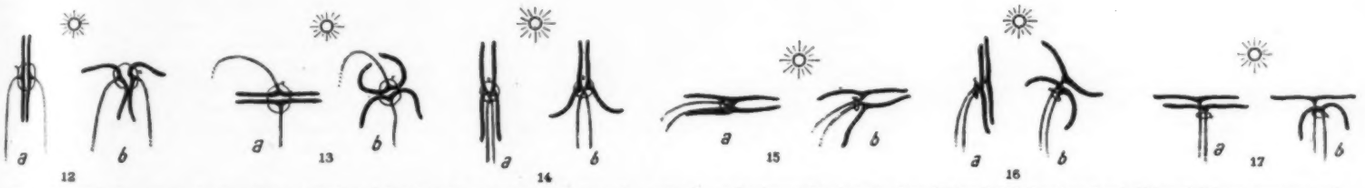


Fig. 11.—Revolution of a strawberry leaf fastened with its upper face towards the sun.

arrested on the third day, the leaf being strangled by its own movement.

"The rapidity of phototropism does not depend on intensity of light. On the contrary, in the case of young stalks, the diffused radiation resulting from intense light appears to retard the movements; these are far more rapid and definite when the lighting is more unilateral. In a dark chamber the light of a lamp or a candle provokes it as rapidly as daylight. Put a young lentil plant in a box completely closed except for a small window, and light a candle opposite this;



Figs. 12-17.—Young nasturtium leaves fastened together in couples by a thread, vertically or horizontally, face to face (12 and 13), back to back (14 and 15), or superposed (16 and 17) rearranging themselves in a short time to expose their upper faces as much as possible to the light

arrangement of the stalks and by their phyllotaxic distribution; they also respond directly and individually to the attraction of the light; each knows how to place itself so as to receive the light normally and on its upper surface, each rearranges itself at need and moves individually, in its own way, and usually without disturbing its neighbors.

"Look at a potted geranium in a room; all the terminal stalks and all the leaves 'look at' the window; turn it with its face to the wall; in two or three days' time all the stalks and all the leaves will have made a semi-turn and will again face the light.[1]

"The movement is usually made by the petiole, which curves and displaces itself exactly like the stalks; but if any obstacle interferes with the curving of the petioles the movement is made by the blade itself, or by that part of the blade which remains free. Let us turn and attach to a wall a leaf of climbing geranium, the blade vertical with its back to the light; in two or three days the leaf will have turned back by pivoting upon the petiole. Vine leaves closely attached to the trellis in similar manner (Fig. 10) have required from fifteen to twenty days to turn entirely back; but their movement was more complex; during the first three days the leaf fastened against the wall lifted its edges; then it began to make a double movement of the petiole of rotation from back to front and of lateral torsion.

"With a cork and two pins fasten the leaf of a strawberry plant to the edge of a horizontal plank (Fig. 11) with its upper face toward the sun. In three or four days, often in less time, the three lobes of the leaf, each separately and in a different manner, will erect itself or curve itself toward the light, either by a curving of the blade or by a torsion of the petiole, whose superficial fibers will present a spiral aspect. Attach by a thread or a pin two leaves of nasturtium (Figs. 12-17) in such manner that their upper faces are propped up vertically or horizontally; by the next day the two leaves have separated to form an X, raised or lowered, and the light penetrates between the blades. The separation continues on following days and the leaf blades succeed in revolving until they are completely folded over. Analogous movements are produced if the leaves are disposed back to back, or if superposed with the superior faces or the inferior faces toward the light. In each case (the experiments may be very varied) the blade of each leaf does exactly what is necessary to bring the light again upon its upper surface. Identical results were obtained with all sorts of plants, trees, shrubs, herbs, showing that the tissue of the leaf itself is endowed with motility as well as that of the stalks and petioles; the swelling called *pulvinal*, or cushion, situated at the base of the petiole, and which has been described as the exclusive

[1]This remarkable phenomenon of the revolving of leaves toward the light is scarcely mentioned by some authors; described in 1758 by Ch. Bonnet in his "Researches on the Habits of Leaves," it has not been since that time, we believe, made the subject of any complementary study.

"With a few variants the results of these experiments on stalks, leaves, and flowers, are constant and can be obtained with different plants and different species and repeatedly on the same subject. The plant

Fig. 18.—A Zinia flower, daisy, etc., with head fastened low down turns up to light in twelve or fourteen hours

always obeys. . . . However, after many tests at short intervals and in different directions, the movements are slower, the *plant seeming to be fatigued.*

"If we expose young lentil plants to vapors of ether under a bell glass, the plants will subsequently rest for many hours, twelve to twenty, without obeying the phototropic law. But it is not certain that we have

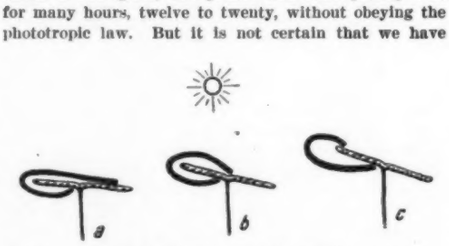


Fig. 19.—A Zinia flower hooded in black uncovers itself in three or four days

here true *anesthesia;* phototropism, in fact, exacts normal vitality in order to manifest itself normally. Sick, feeble or bruised subjects obey badly. Very supple young plants are particularly sensitive and mobile. At a certain age stalks which have become too rigid will no longer curve themselves, but at any age the leaves and flowers will almost always turn toward the light in a longer or shorter time.

"Sometimes, but very rarely, the plant which is tired or unhealthy will not succeed in making the movement. We have seen a pear tree leaf die while trying to turn to the sun by torsion of its petiole. The torsion had been so accentuated that the circulation was suddenly

[2]In our bibliographic researches we have found no mention of this recurving of flowers, nor experiments of this kind, but it is well known that certain flowers follow the course of the sun, while others close at night. The Nile lotus closes its flowers and withdraws them into the water, to reappear at sunrise.—[Ed. Grimard.]

in two or three hours the stalk will curve completely, and the terminal leaves will be directly opposite the center of the window (Fig. 9). We know, too, what length of stalk and what extraordinary curves are shown by plants in cellars, trying to reach the light. 'When a vegetable is deprived of light it lengthens its stalks as if it sought some issue to regain the light it lacks.'[3] It seems that the less the plant's appetite for light is satisfied, the more marked its efforts to get it.

"Another very remarkable fact is that phototropic movements begun in the day continue at night, and that the revolution of the leaves and flowers may even be made entirely in obscurity. In fact, if we cover with a box a strawberry plant (Fig. 11a), one leaf of which has been revolved away from the sun, the latter will nevertheless erect itself in two or three days *in the direction opposite to that whence the light last came.*

"How can we explain these diverse manifestations of phototropism in plants? The old naturalists tended to see in the heliotropic attitudes of leaves and flowers an instinctive orientation. Subsequently an effort was made to explain them by purely physical causes.

"Darwin, who studied with care the development of those movements which have been designated as 'circumnutation' of stalks and roots, compares these with the subconscious movements of the lower animals. The heliotropic impulses of the stalks and leaves would arise, by adaptation to a useful purpose, from circumnutation, and would be 'regulated but not completely determined by the direction of the incident light.'

"Other authors regard the phototropic curvings as the result of a direct mechanical action, of a sort of pressure of the luminous rays on the stalks and petioles or of a modification of the turgescence and of the growth of the side exposed to the light. This mechanical theory, held particularly by the Germans, has of late been the one most generally accepted.

"The preceding observations and experiments demonstrate, we believe, that there we have in the phototropism of plants, as in that of animals, not a passive mechanical phenomenon, nor simply a modification of growth due to the light, but the manifestation of a sensibility and a motility[4] which is revealed, indeed, in many ways.

[3]Gaston Bonnier. "The Vegetable World." E. Flammarion, publisher, Paris.

[4]Certain phenomena of sensibility and of mobility observed in various rare plants—sensitive plant, sun-dew, oscillating sainfoin, etc.—have been much discussed and studied since the time of Linnæus. Apropos of these, Geoffroy Saint-Hilaire recognized "automatic movements" in vegetables, and Claude Bernard "appearances of voluntary movements." Paul Bert having observed that anesthesia by ether abolished in the sensitive plant contact movements, but not the periodic movements, supposed that this plant has, like animals, voluntary movements and others comparable to those dependent upon the sympathetic nerves. The French botanist, Edouard Hecke, has moreover brought to light certain very remarkable movements of flowers and seeds, and Maeterlinck has assembled exceedingly curious facts upon this subject in a recent book.

"It is not an exaggerated view, we believe, to behold in vegetable phototropism also the manifestation of an intelligent directing function[a] in the sense that it presides in the different cases of adaptation of the means to the end, and permits the individual to defend itself, and to reach that which it has need of in spite of the most diverse obstacles.

"Like animals plants seek their food materials, air, water, sun; know how to advance toward them and find them, giving proof of special sensibility and of an admirable sense of direction. Regarding them more closely they appear to be highly perfected creatures, near enough to ourselves, even superior from certain biologic points of view.

"The physician and the hygienist find in them more than one example to follow in the art of living and of healing, and ought particularly to study and seek to imitate their marvelous manner of utilizing solar energy."

[a] "It seems that the plant acts to preserve itself with sensibility and discernment."—Ch. Bonnet (*loc. cit.*).

Photo-Electric Phenomena*

Some Relations of Light to Long Distance Wireless Telegraphy

By Dr. J. A. Fleming, F.R.S.

THE phenomena of light and electricity are so closely connected that we may truthfully say the study of both is embraced within the confines of a single branch of science.

The term photo-electricity is, however, restricted to the description of a particular effect, viz., the power of light of certain kinds to cause an electric discharge or leakage of electricity from many substances, or under some conditions to produce an electric charge, or electromotive force or ionization.

The starting point for this subject is found in an observation Hertz made in the course of his celebrated researches on the production of electric waves, in which he noticed that the discharge in the form of an electric spark between two balls is facilitated when light from another spark falls upon them.

This effect can be shown by a special form of apparatus devised by the writer. It consists of two upright strips of wood carrying copper strips which are connected at two places by a pair of spark balls, adjustable as to distance. The lower pair of balls are inclosed in a glass box, while the upper pair are exposed in the air. The copper strips are connected to the inner and outer coatings of a pair of Leyden jars, and these again to an induction coil. When the coil is in action, electric sparks jump across between the balls. We can then adjust the two spark lengths so that the sparks always take place between the two bottom balls in the glass box, because these balls are a little closer than the upper pair. If we now illuminate the upper balls by the light from an electric arc, or a piece of burning magnesium wire, or the light from another electric spark between zinc balls, or else points of invar, which is a nickel-iron alloy, we see that the spark discharge at once takes place between the upper balls. This effect is not due to the visible or eye-affecting light, because the interposition of a sheet of glass or mica stops the effect. On the other hand, a sheet of transparent quartz does not. Hence we infer that the action is due to the ultra-violet rays in the light, or those of very short wave-length. The material of which the spark balls acted upon are made does not seem to have much influence. Experiment also shows that the chief part of the effect is due to the action of the ultra-violet light on the negative spark ball.

These observations were made by Hertz in 1887, and immediately suggested lines of research to others. Hallwachs soon afterwards discovered that the same kind of light could discharge electricity from a negatively electrified zinc plate.

If a plate of zinc, or better, magnesium which has been recently well polished with emery paper, is placed on an insulating stand connected with a gold leaf electroscope, and a charge of negative electricity given to it, it is found that the charge rapidly disappears if the plate is exposed to the light of an arc lamp. The experiment succeeds better if an uninsulated brass grid or plate of coarse gauze is placed between the plate and the light. If the plate is oxidized or tarnished, or has been long exposed to the air since polishing, then the discharge of negative electricity from it proceeds much more slowly. If the plate is positively electrified, the discharge does not take place, or but very slightly.

We may show the experiments in another way. If we insulate a piece of brass gauze and connect it to an electroscope and charge it with positive electricity, then, if the insulation is good, there should be no leakage. If then we hold near to the gauze a polished plate of zinc, magnesium or aluminium which is uninsulated, we find that no discharging effect takes place until light from an arc lamp or other source of ultra-violet light illumines the polished plate, and then the positive electricity of the electroscope is discharged.

These experiments may be modified by employing a very sensitive galvanometer in place of an electroscope. If we connect to the negative terminals of a high potential battery a polished zinc plate, and to the positive terminal a piece of metal gauze, and insert in the circuit a galvanometer, and then bring the gauze near to the zinc plate, we find no current as long as the zinc plate is not illuminated. If, however, a strong light, rich in ultra-violet rays, is thrown through the gauze on to the zinc plate, the galvanometer at once gives indications of an electric current which is called a photo-electric current.

LIGHT EFFECTS ESCAPE OF ELECTRONS.

The consideration of all these effects shows that there is a leakage of negative electricity from negatively electrified bodies when they are exposed to light, chiefly ultra-violet light. In modern terminology we say that light falling on certain substances causes an escape of electrons from them.

Many things affect this photo-electric discharge.

First, the nature of the body itself. Some are highly photo-electric, such as zinc, magnesium, potassium, sodium, rubidium. Broadly speaking, the most oxidizable metals are most photo-electric, and the photo-electric order is very roughly that of the electro-chemical series, the most electro-positive being the most photo-electric.

Secondly, the physical nature of the surface, whether polished or tarnished, smooth or rough, has a great deal of influence; and,

Thirdly, the nature of the atmosphere or surrounding gas.

A convenient method of exhibiting these facts and testing various substances is by an apparatus as follows: It consists of a box within which is contained a series of spark gaps between invar points. The ultra-violet light radiated passes out of an aperture covered with a thin transparent quartz disk and passes down a tube and falls upon a disk of the substance under test. Around the outside of the tube, but so protected as not to be affected directly by the light, is an insulated metal ring which is connected to an electroscope. This ring is given a charge of positive electricity. When the spark light shines on the disk under test, it liberates from it negative electrons. This discharge passes through the air and discharges the positively charged metal ring. By observing the time taken for the electroscope to be discharged we can compare various substances, solid, liquid or in powder, with each other with regard to their photo-electric activity in air. The results, however, of such observations in air must be interpreted with caution. It must be noted in the first place that the radiation most effective in the case of one metal or substance is not so in another, and, moreover, the nature of the surrounding atmosphere affects the result. Also, we have to take into account a very noticeable effect which is commonly called *photo-electric fatigue*. It is found that the sensitiveness of a freshly cleaned surface of metal rapidly decreases if the metal is left exposed to the air. It has been found that this depends much on the size of the vessel in which the substance is kept. In the open air photo-electric fatigue progresses most rapidly, but less so if the body is kept in a closed chamber. The term "fatigue" is not very appropriate, because the photo-electric sensitiveness is not recovered on resting.

PHOTO-ELECTRIC DETERIORATION.

Elster and Geitel found that a freshly polished zinc surface lost half its photo-electric sensitiveness in five minutes. Hoor noticed that for freshly cleaned metals, zinc, copper and brass, the activity was reduced one tenth of its initial value by exposure for forty-eight hours to the air. The effect, however, is not due or wholly due to oxidation of the surface, because it takes place in hydrogen as well as in air. Again, it takes place in the case of such insulating materials as sulphur, shellac and paraffin, which are not oxidizable. It would be more appropriate to call this falling-off the *photo-electric deterioration*.

The reasons for this photo-electric deterioration have not yet been fully ascertained, but as far as the evidence goes, it seems to be due to a peculiar condition of the gaseous layer adhering to the surface of bodies. It is suspected that in some cases it is due to the formation of a film of hydrogen peroxide, which is extremely absorbent of ultra-violet light, and this again may be due to the action of the ultra-violet light on aqueous vapor in the air, or moisture condensed upon the surface, according to the chemical equation $2H_2O = H_4O_2 + H_2$.

Experiments seem to prove that pure, clean metal surfaces in a very high vacuum show no photo-electric fatigue.

HOW TO OBTAIN CONSISTENT RESULTS.

Accordingly, experimentalists sooner or later realized that consistent results can only be obtained when we experiment with freshly prepared surfaces in a very high vacuum. This, however, introduces great experimental difficulties, and it is necessary to devise methods for distilling or preparing the metal or other substance in the vacuous tube. Some years ago the writer described methods for doing this in the case of the liquid potassium sodium alloy, which is very highly photo-electric, and, moreover, sensitive to ordinary visible light. Small lumps of potassium and sodium are placed in a glass tube, the weights being in atomic ratio, viz., about 2 to 1. When this is melted *in vacuo* it produces a liquid alloy resembling mercury, which can be tilted off from the solid dross or oxide. If such liquid alloy is placed in a clean part of the exhausted tube provided with an electric connection, consisting of a platinum wire sealed through the glass, and if there is a clean platinum plate, also with an external electrode placed over and near to the alloy surface, we can observe the following facts:

First, the alloy surface rapidly discharges negative electricity when light from an arc lamp falls upon it. Also when illuminated the alloy discharges positive electricity from the platinum plate, provided the alloy is kept connected to the earth. Most remarkable of all is the fact that the alloy when illuminated actually generates an electric current. If we connect a sensitive galvanometer to the alloy and to the platinum plate, then in darkness there is no electric current; but when a bright light falls on the alloy surface the galvanometer indicates a current, and this current is in the opposite direction to that which would flow under the volta contact potential difference. That is to say, the negative electricity comes out from the terminal connected to the platinum plate and flows through the galvanometer back to the terminal connected to the alloy. This proves that light causes an emission of negative electrons from the alloy surface, which has an electro-motive force greater than the contact E.M.F. due to platinum and potassium.

The strength of the photo-electric current varies with the color of the light thrown upon it, that is, with the wave-length. Elster and Geitel found that this negative leak is greater for potassium than for sodium, provided we employ white or blue light, but for yellow light sodium is more photo-electric than potassium, and rubidium is vastly greater than either of them, both for white and for yellow light.

PHOTO-ELECTRIC METALS.

The writer showed that several such photo-electric cells could be joined in series to make a photo-electric battery. If it were possible to obtain the rare metal rubidium in large quantities, it would be possible to construct a rubidium photo-electric battery of a large

*From "The Year Book of Wireless Telegraphy and Telephony, 1916." Reproduced from *The Wireless Age*.

number of cells, which would create a considerable electric current merely by illuminating the rubidium surface. It is needless to say that the energy represented by this current would be drawn from the light energy.

We may next pass on to notice some curious and interesting facts with regard to the photo-electric properties of various classes of substances, solid and liquid.

It has been mentioned that the most photo-electric metals are the electro-positive ones, rubidium, potassium, sodium, magnesium, zinc, aluminium, etc. The least sensitive are the electro-negative and non-oxidizable metals, platinum, gold, silver, palladium. Metals such as copper, iron and nickel occupy an intermediate position.

There are, however, many compounds of metals and non-metals which are highly photo-electric, such as the sulphides and iodides, especially the sulphides. These sulphides may be roughly arranged in the following order, the most photo-electric standing first: Sulphide of lead, copper, manganese, silver, tin, iron, chromium, bismuth, nickel, antimony, zinc, cadmium, cobalt and molybdenum. The native sulphide of lead called galena and the native double sulphide of copper and iron called chalcopyrites, or copper pyrites, are markedly photo-electric; while the native sulphide of molybdenum called molybdenite is very insensitive.

PHOTO-ELECTRIC EFFECTS.

Again, the phosphorescent sulphides of barium, calcium and the alkaline earths are very photo-electric. Fluorspar, which is a fluoride of calcium, is also photo-electric; and silver iodide is said to be remarkably photo-electric under ultra-violet light.

Another important class of substances which exhibit photo-electric qualities are the aniline dyes. Not only is anthracene photo-electric, but also eosin, fluorescine, fuchsin; and aniline green and violet are very sensitive in the solid as well as in solutions.

There is a certain connection, in fact, between fluorescence, phosphorescence and photo-electric leak or discharge, and, broadly speaking, the fact that a substance is fluorescent is generally an indication that it is photo-electric and will lose negative electricity when illuminated by ultra-violet light.

With regard to liquids, many experimentalists agree that pure water shows no photo-electric effect when illuminated by the electric arc. Soapy water is intensely non-photo-electric, and even very sensitive materials, such as clean zinc, lose sensitiveness if smeared with soapy water.

Generally speaking, fluorescent liquids are photo-electric, and I have noticed a marked leak of negative electricity from the surface of paraffin oil, which is well known to be fluorescent.

The fluorescence of a body is a property of it in virtue of which it has the power to create a change in refrangibility of light. It absorbs, say, ultra-violet or non-luminous light and radiates or emits violet or visible light. A typical instance of this is a solution of sulphate of quinine.

At this point we may with advantage consider in outline the explanations which have been offered to account for photo-electric effects.

According to modern views, we regard electricity as having an atomic structure, and the atoms of negative electricity, called electrons, are constituents of chemical atoms. All electric conduction and electric currents are considered to be due to a movement or drift of electrons in or between chemical atoms or molecules. All radiation is effected by oscillations of electrons, which create ether or electric waves when the velocity of the electron is being changed. Hence an electron radiates only when it is being accelerated. Again, the forces binding together atoms into molecules are electric forces due to electric charges. Hence we may classify the electrons in a certain manner depending on function. We have to consider the conduction electrons, the radiation electrons, and the valency electrons. This does not imply that the same electron may not function in all three ways. It is merely a classification for the sake of distinction.

CONDUCTION ELECTRONS.

The conduction electrons may be regarded as the molecules of a kind of gas. They are assumed to be in rapid, irregular movement, and, in good conductors, to be about as numerous as the chemical atoms. Their velocities are distributed according to the same law as those of gas molecules. These free electrons cannot, however, escape from the conductor, because if they did they would leave it positively electrified. In the next place we have those electrons the vibrations of which create the radiation or spectrum of the body when incandescent or luminiscent. Lastly, there are electrons more or less loosely attached to the atom, up to the number of eight, which by entrance to or exit from the atom give rise to the atomic electric charges proportional to the chemical valency, and so effect chemical combination.

The question then arises, to which of these classes do the electrons belong, the escape of which constitutes the photo-electric discharge? If light discharges negative electricity, this implies that light causes an escape of negative electrons. We then ask, what electrons are these, and how is this escape brought about?

Dealing first with the conduction electrons, it may be noticed that there is no good evidence that these are liberated in the photo-electric effect. If they were, one would think the body should become a worse conductor when illuminated. Since, however, in good conductors the conduction electrons are extremely numerous, probably about as numerous as the atoms, there might be a considerable loss of conduction electrons without sensible or measurable loss of conductivity. On the other hand, one well-known case in which light affects conductivity is that of selenium. The effect of light falling on it is to increase conductivity. Again, light is said to increase the conductivity of sodium vapor, and Arrhenius found that the haloid salts of silver increase in conductivity under the action of light.

CONDUCTIVITY AND ULTRA-VIOLET LIGHT.

There is no well marked case of decrease in conductivity under the action of ultra-violet light. The author has found one interesting connection between photo-electric sensitiveness and conductivity. It is well known that the contact between certain pairs of substances has a unilateral conductivity. Thus the contact between zincite (native oxide of zinc) and chalcopyrite (copper pyrites) conducts negative electricity better when flowing from zincite to chalcopyrite across the junction than in the opposite direction. The same is true for a junction between molybdenite (native sulphide of molybdenum) and copper, also between plumbago (carbon) and galena (sulphide of lead). Again, a junction of tellurium and aluminium, silicon and steel, carbon and steel, and several other pairs of metals and non-metals, such as gold and iron pyrites (native persulphide of iron), have similar unilateral conductivity.

It has been found that almost without exception, of these pairs of substances which so act, one of them has great photo-electric sensitiveness and the other one small. The two minerals which compose a rectifying contact always differ greatly in photo-electric sensitivity or power. The one which loses negative electricity most easily under the action of ultra-violet light is always the sulphide, or else the good metallic conductor. The largest negative current flows across the junction from the material of small photo-electric activity to the one of large activity. For example, chalcopyrite is vastly more photo-electrically sensitive than zincite, and the largest current flows across the junction when the zincite is the negative terminal or electrode, or is attached to the negative pole of the battery.

SENSITIVENESS DEPENDENT ON MOLECULAR GROUPING.

Whatever may be the proper interpretation of these facts it appears clear that photo-electric sensitiveness is not an atomic property, but is a molecular one, and depends also on molecular grouping. Also we cannot trace any definite relation between this property and electric conductivity. Accordingly, we are obliged to assume that there are in connection with certain molecules or groupings of atoms certain electrons which can be set free by light of short wave-length.

The question then arises: How does the light act? Is it a simple resonance action in virtue of which the luminous vibrations work up these loosely attached electrons to such an amplitude that they break loose from their moorings and are shot off, just, for instance, as water waves might cause a boat to break loose and drive it away? If this were the case, it would seem most probable that the more intense the light—that is, the greater the amplitude and energy of the light waves—the more effective it would be, and the greater the velocity of the electron which is detached and flung out. Also it would appear likely that high temperature in a body, by increasing the electronic motion, should promote or increase photo-electric effects. But two very remarkable facts have been discovered which are quite inconsistent with this resonance theory. The first is that the maximum velocity with which the electrons are shot off when the sensitive substance is exposed to light is independent of the temperature, as long as the body is not oxidized or otherwise altered by heating or cooling. Thus, for the noble metals it is invariable between a red heat and the temperature of liquid air.

The second fact is that this maximum electronic velocity is independent of the intensity of the incident light, and depends only on the frequency; but no electrons at all are liberated if the frequency falls below a certain value. There is a special velocity for each substance. For a given metal or substance the maximum velocity with which the electron is shot out increases with the frequency of the light, and the electronic energy is proportional to the excess of this frequency above a certain minimum, which must be exceeded in order that any photo-electric effect may take place at all.

DISCUSSION OF A THEORY.

It appears, therefore, that there is a certain energy required to get the electron away from its atom or to detach it from home; and that over and above this the energy absorbed is proportional to the frequency of the light and to a constant called Planck's constant. The difficulty which we are called upon to face in endeavoring to explain these facts by the ordinary undulatory theory is as follows: A molecule cannot absorb more radiant energy than falls on its surface or projected area. Now the cross section of a molecule is something of the order of 10^{-15} of a square centimeter. It is certain that light of suitable wave-length which falls on a photo-sensitive surface, giving to it per second energy equal to 1 erg per square centimeter, will produce a photo-electric effect. The liberation of 1 electron requires at least 10^{-12} erg. Hence the above illumination would have to fall for 1,000 seconds on each molecule to impart to it the necessary energy to expel an electron. It is, however, found that the photo-electric effect, if it takes place at all, happens instantly the illumination begins. The conclusion is inevitable that the ordinary undulatory theory, in which the light energy is assumed to be spread uniformly over the wave front, cannot, taken by itself, adequately explain photo-electric effects.

It has been, therefore, necessary to introduce modifications. Sir Joseph Thomson has suggested that in the light wave the luminous energy is not distributed uniformly over the wave front, but is concentrated at certain points in it. This supposition is somewhat analogous to a view taken by Faraday in his "Thoughts on Ray Vibrations." On the other hand, we have more recently the hypothesis developed by Planck, Einstein and others, that radiation is not emitted continuously, but in gushes or bundles, which are, in effect, indivisible units of energy and all absorbed as a whole. These gushes of radiant energy are called *quanta*, and the size of these quanta is proportional to the light frequency and to a constant called Planck's constant. Our ordinary measure of radiation is therefore an average, and the maximum value at any moment may greatly exceed the average value. We may compare this view of radiation with the ordinary one by the illustration of carrying water in buckets, say, to put out a fire, as contrasted with pumping a steady stream of water through a hose. In the bucket-carrying process the water arrives in gushes or lots, but the average water delivered per hour is very much smaller than the maximum delivered at the moment when one bucketful is just being poured on the fire.

This view of the case gives to the radiant energy an atomic character, and we can speak of these quanta as atoms of energy.

PHENOMENA NOT FULLY EXPLAINED.

In spite of the fact that this quantum theory helps us to explain very easily photo-electric effects, and also many other matters, such as the distribution of energy in the spectrum and some facts connected with the ionization of gases by ultra-violet light, yet this theory seems hopelessly irreconcilable with the fundamental facts of interference which must be primarily explained. The well known fact that two rays of light can, under certain conditions, extinguish each other at a point in space is one of the chief truths of physical optics, and is at once explicable on theory of a wave motion. But it is not interpretable on any corpuscular theory of light or radiation. Hence, although this quantum theory of radiation has attracted much attention and exercised much ingenuity, it is probably correct to say that the leading physicists have felt it does not give us a final theory and that photo-electric phenomena are still not yet fully explained.

CASE OF GASES.

We pass on then to consider photo-electric effects in the cases of gases, particularly the circumstances under which light of short wave-length can ionize gases or produce in them positively and negatively electrified particles.

If an electron or negative corpuscle is extracted from a chemical atom it leaves the atom positively electrified. If, on the other hand, a neutral atom takes up an electron it becomes negatively electrified. The extraction of an electron requires the expenditure of a certain energy, and the electron itself is a charge of

negative electricity equal to 4.772×10^{-10} electrostatic unit or 16×10^{-20} coulomb.

Hence we may represent the work required to extract an electron from an atom as proportional to a certain voltage called the ionizing voltage. This ionizing voltage multiplied by the electron charge gives the ionizing work, which last may be measured in ergs. The ionizing energy is of the order of one-billionth of an erg.

The ionizing voltage varies from about two to twelve volts for various atoms, being greater for electro-negative atoms than electro-positive ones. For gaseous oxygen the ionizing voltage is nine volts, and the ionizing energy about 15 billionths of an erg.

Now experiment shows that ultra-violet light of very short wave-length can ionize gases, and it has also been proved that there is a connection between the length of the longest wave of light which can effect this ionization and the ionizing voltage. The product of this longest wave-length and the voltage is always a number near to 11,000 or 12,000, if the wave-length is measured in Angstrom units (A.U.). Thus for sodium the ionizing voltage is 2.1 volts, and hence the maximum wave-length is 5,500 A.U.

Hence wave-lengths longer than this will not liberate negative electricity from sodium.

For oxygen, the ionizing voltage is nine, and hence wave-lengths longer than about 1,350 A.U. will not ionize oxygen. This wave-length is about two octaves higher up in the spectrum than ordinary blue-green light. It therefore requires ultra-violet light of very short wave-length to ionize gaseous oxygen. It is a difficult matter to prove experimentally the ionization of gases by ultra-violet light. The gas must be contained in some vessel, and have a window of some material transparent to light of very short wave-length. Glass is very opaque to this light, and even quartz does not transmit light of wave-length less than about 1,850 A.U. Almost the only substance available is fluorite (fluoride of calcium). We have to avoid spurious effects due to photo-electric action of the light on the walls of the vessel or upon dust particles in the gas. Nevertheless, by suitable precautions it can be shown that light of wave-length less than about 1,400 A.U. can ionize—that is, produce positive and negative ions in a gas.

SUNLIGHT AND ATMOSPHERIC GASES.

The question then arises whether the light of the sun thus ionizes the atmospheric gases. It has been shown by Huggins and by Cornu that the light which reaches the surface of the earth from sun and stars contains no wave-lengths shorter than about 2,950 A.U. The spectrum is terminated pretty sharply at that point.

Now the sun is a body at a very high temperature, and must certainly radiate light of very short wave-length. The absence of the very short wave-lengths from the light received at the surface of the earth seems therefore to prove that there is an absorption of ultra-violet light of very short wave-length in the upper levels of the atmosphere.

This light possibly ionizes these higher levels. Ionization in gases is proved by the gas acquiring electric conductivity. An un-ionized gas is a perfect non-conductor. It is found that air even near the sea level has always some small degree of electric conductivity. This, however, cannot be due to true ionization by solar light. It may be due to photo-electric action on dust particles or to radio-active matter in the sea or soil.

STRONG IONIZATION IN UPPER ATMOSPHERE LEVELS.

There are well known phenomena in connection with wireless telegraphy which seem to indicate the existence of somewhat strong ionization in the upper levels of our atmosphere which, in part at least, are due to ionization by solar light because they vary with day and night. Such, for instance, as the now well known day and night effect on radio-telegraphy discovered by Senator Marconi in 1902, in virtue of which signals are in general received at greater distances by night than by day.

In addition to this there seems to be a more permanent ionization of the very high levels of the atmosphere which is not due to true light ionization, but possibly due to the projection of negatively electrified corpuscles from the sun propelled by light pressure and ionizing the upper layers of our atmosphere by impact.

The sun is an incandescent body, and the light-giving portion of the sun called the photosphere is probably in the main composed of carbon. Hence, like other incandescent bodies, such as the filament of an electric lamp, it projects from it electrons or atoms of negative electricity. These, as they pass outwards through the superimposed solar atmosphere, collect molecules round them and form small masses called negative ions.

It was shown by Clerk Maxwell that light or ethereal waves exercise a pressure upon bodies upon which they fall.

At the earth's surface the solar light pressure only amounts to 2.8 pounds per square mile taken perpendicularly to the light rays. At the sun's surface, owing to the vastly greater intensity of the light, it amounts to no less than fifty-eight tons per square mile. One cubic mile of sunlight near the sun's surface contains energy equal to 302,300 foot-tons, enough to throw twenty of H.M.S. "Elizabeth's" fifteen-inch shells over the top of Mont Blanc. Consider, then, a small particle of matter poised in space near the sun's surface. Gravity at that place is twenty-seven times greater than at the earth's surface. Hence the particle is pulled toward the sun with a force twenty-seven times greater than its weight on the earth. But the light-pressure is pushing it outward. The gravitation pull varies as the mass or as the cube of the diameter, whereas the light-pressure varies as the surface or as the square of the diameter. Hence if the particle is made smaller the light-pressure decreases much less fast than the gravitation attraction, and for a certain diameter—viz., about 0.00013 centimeter or 13,000 A.U., if the density of the material is equal to that of water—the push would just balance the pull. Suppose the particle made still smaller, then it can be shown that the light-pressure would not increase indefinitely relatively to the gravitation pull, but would come to a maximum for particles of unit density and of a diameter equal to 1,600 A.U. This is about twice the thickness of very thin gold leaf. For such a small particle the solar light-pressure near the sun's surface would be ten times greater than the solar gravitation, and the particle would be flung away from the sun with an acceleration to start with of about two kilometers per second. Hence it would cover the distance between the sun and the earth in a very few score hours, and would enter the earth's atmosphere, if it happened to hit it, with an enormous velocity.

TRANSIT TIME FROM SUN TO EARTH.

The writer has calculated for particles of three sizes what this time and velocity would be. Taking three sizes, viz., 1,600 A.U., 5,000 A.U. and 10,000 A.U., the first is about the wave-length of the shortest ultra-violet light easily made, the second that of the wave-length of blue-green light, and the third that of ultra-red or heat rays. The times of transit from sun to earth and final velocities are as follows:

Diameter of particle in Angström units.	Time of journey in hours from sun to earth.	Velocity on reaching earth in kilometers per second.
1,600	25	1,700
5,000	55	800
10,000	112	350

Hence the energy contained in quite a small quantity of this dust is enormous. If we suppose 1 kilogramme = 2.2 pounds of the dust of the above sizes to arrive at the earth's atmosphere, the energy it would bring with it would be as follows:

Diameter of particle.	Energy in horse-power hours per kilogramme.
1,600 A. U.	540,000
5,000 A. U.	120,000
10,000 A. U.	45,000

Therefore as much of this dust as one could carry in one's pocket would convey to the earth enough energy to run one of our large battle cruisers at full speed for eighteen hours!

This energy must expend itself in ionizing the upper layers of the earth's atmosphere, which consist principally of hydrogen and helium. Hence the outer layers of the atmosphere are probably in a state of strong permanent ionization.

We have then to recognize, roughly speaking, three layers in the earth's atmosphere, not, however, sharply delimited from each other, in which ionization occurs. In the upper or highest layers of the atmosphere there is strong permanent ionization with a predominance of negative ions. In the middle layer there is ionization, both positive and negative, due to solar ultra-violet light of short wave-length which is strong by day but weaker by night. In the lower layers near the earth there is weak ionization, chiefly due to radio-active matter in the soil or sea, or to photo-electric action on dust particles or ice particles in the air.

This permanent and varying ionization reveals itself by its action on the long electric waves used in wireless telegraphy and upon the stray waves produced by atmospheric electric discharges. This action seems based upon the variation in velocity produced on such electric waves when they pass from a strongly ionized to a weakly ionized region or *vice versa*.

Although it has not been proved experimentally that strongly ionized air has a less refractive index for long electric waves, yet it has been shown mathematically by Dr. W. H. Eccles that if the ions are a certain class of heavy ion the effect is equivalent to a reduction in refractive index of the medium. If this conclusion is valid, then it can be shown that if the bounding surface of the heavily ionized air is fairly well marked a ray of long wave-length radiation would suffer a rapid refraction when incident on the surface equivalent to reflection. Hence it may be concluded that there is on the underneath side of the heavily ionized atmospheric layer at great altitudes an effect equivalent to an *inverted mirage* by which electric rays sent upward are bent down again.

If, however, the bounding surface of this heavily ionized layer is underlaid by other layers of gradually decreasing ionization, the reflective effect of the upper layer may be greatly diminished. In this manner it is possible to explain some of the curious variations in strength of radio-telegraphic signals at or about sunrise or sunset and the extension of range of freak signals at other times by the refraction or bending downward of the electric rays.

We have thus good grounds for believing that atmospheric photo-electric effects play a very important part in long distance wireless telegraphy, but it will require many years of careful observation before all these phenomena are disentangled and explained.

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Table of Contents

PAGE

The Energy of the Universe 99

The Effect of Successive Removal upon the Rate of Regeneration.—By Charles Zeleny 99

The Pearl Fishing in the Persian Gulf.—By Edwin E. Calverley.—4 illustrations 100

On a Precision Method of Uniting Optical Glass.—By R. G. Parker 102

Modern Technical Work in Italy.—10 illustrations 103

Capillary and Electrocapillary Chemistry.—II.—By W. C. McC. Lewis 105

Fennel and Its Uses 107

The Phototropic Sense in Plants.—19 illustrations 108

Photo-Electric Phenomena.—By J. A. Fleming 110